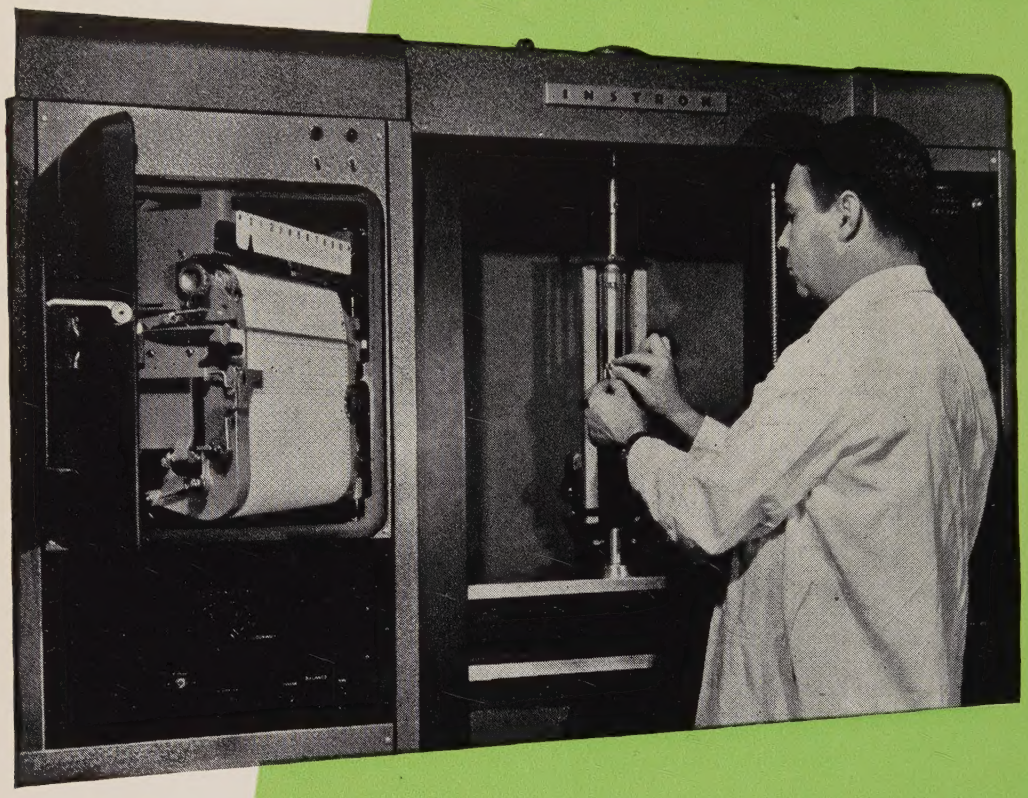
Tappi

PUBLISHED BY THE TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY

SEPTEMBER 1951

NOW... High Wet-Strength with

KYMENE



Kymene 138, formerly called Resin 138, and Kymene 234 are firmly established as superior low-cost wet-strength resins for use in all types of wet-strength papers and paperboard—both in the stock system and for surface applications.

These strongly cationic resins are in solution, ready to use. They may be diluted with water to any desired concentration. No acid additions or aging periods are needed before using Alum is not required.

The effectiveness of Kymenes is demonstrated at Hercules' laboratories by the Instron, shown above. This highly sensitive equipment measures wet and dry tensile strength, and other important properties of wet-strength papers.

Write for technical data and sample.

HERCULES POWDER COMPANY
INCORPORATED

Paper Makers Chemical Dept., 967 King Street, Wilmington, Delaware

SIZING MATERIALS AND CHEMICALS FOR PAPER

"KYMENE" IS A HERCULES TRADEMARK

PP51-6

IMAGINE...

America without paper!

No more paper towels! Not even disposable tissue of any kind! Think how disruptive *that* would be to America's mobilization . . . to millions of U. S. homes . . . to every school child, housewife, defense worker . . . and to the Armed Forces themselves. From paper napkins to industrial tissue . . . a vast range of paper products have become essential parts of our economy . . . and contribute to the nation's health and security. Thanks to tissue, for example, America no longer has to put a cold in its pocket. Epidemics are reduced, production time is conserved. *So don't take paper for granted!* Use it wisely . . . protect its production . . . to keep America strong.

America depends on PAPER

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PREPARED IN THE PUBLIC INTEREST BY BELOIT IRON WORKS, BELOIT, WIS.
MAKERS OF HIGH-SPEED, HIGH-PRODUCTION PAPER MACHINERY SINCE 1858

CAN YOU USE REPRINTS? This is one of a series of messages Beloit is running in *Fortune* Magazine to remind the U.S. of paper's importance. Reprints for bulletin boards and mailing available. Write to Beloit Iron Works, Beloit, Wis.

"Take the colored boxes up front"

Colored corrugated shipping containers are a bright spot in a desert of nondescript tans and browns. When colored boxes come in, the dealer knows whom they're from—what they contain, and where he wants to put them.

A distinctive *color* becomes associated with a manufacturer or wholesaler. It enhances his prestige with the dealer. And it creates a "family resemblance" among all his products. The retailer can use the colored boxes as a display base.

Show your customers how to profit by a switch to *colored* corrugated containers. Our Technical Staff will help you with dyes specially selected for the job. Write: E. I. du Pont de Nemours & Co. (Inc.), Dyestuffs Division, Wilmington 98, Delaware.

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Du Pont basic dyes

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Du Pont acid dyes

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Monastral* Fast Blue BWD or BFP Paste
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Lithosol* Pigments

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More color makes more business ...for your customers and you

Du Pont Dyestuffs

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BETTER THINGS FOR BETTER LIVING ... THROUGH CHEMISTRY

Weyerhaeuser Reports efficient chemical and heat recovery with B&W Unit

An Example of B&W Engineering for Economy

The entire paper industry has watched with interest each step in the development, by Weyerhaeuser Timber Company, of a great, integrated wood-use center at Longview, Wash. B&W is especially gratified by Weyerhaeuser's report of satisfaction with the performance of their Kraft B&W Recovery Unit at this location.

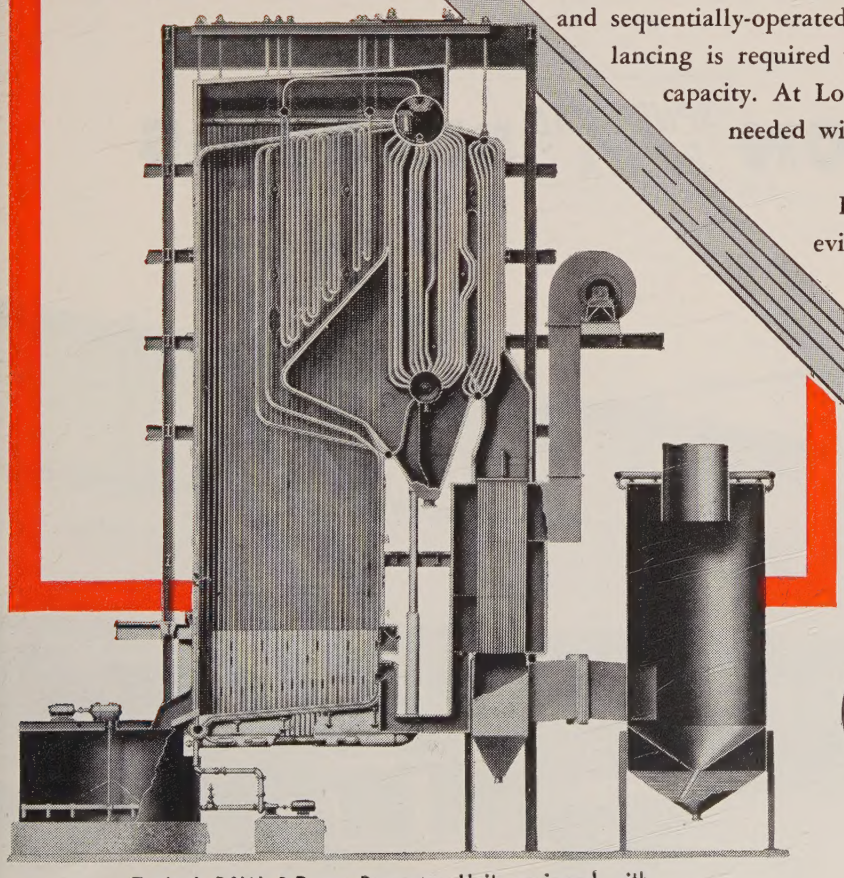
A second B&W unit, of 150 ton capacity, was placed in service at Springfield, Ore., in December, 1950; recently, a third unit was ordered (for Longview) with a capacity of 300 tons.

Operating at 650 psi, 700 F, the Longview installation delivers 120,000 lb. of steam per hr; chemical reduction is 96 per cent.

Because of skillful operation, combined with efficient boiler design and sequentially-operated, retractable soot blowers, no routine hand lancing is required while the Springfield unit operates at rated capacity. At Longview, a small amount of hand lancing is needed with the unit operating at 30 per cent above rated capacity.

Performance of this unit adds to the tangible evidence of B&W's prominence as designer and builder of modern chemical recovery equipment for the pulp and paper industry.

The Babcock & Wilcox Company,
85 Liberty St., New York 6, N. Y.

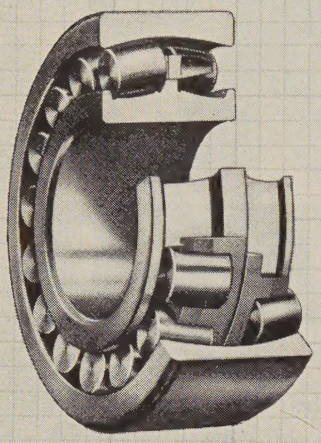


Typical B&W 2-Drum Recovery Unit equipped with B&W Cyclone Evaporator

B&W BABCOCK & WILCOX

P-760

high quality pulp screening



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These self-aligning bearings automatically compensate for shaft deflections—prevent binding stresses. Finest steels, precision workmanship and special heat-treating methods assure day-in, day-out dependability of Torrington Bearings.

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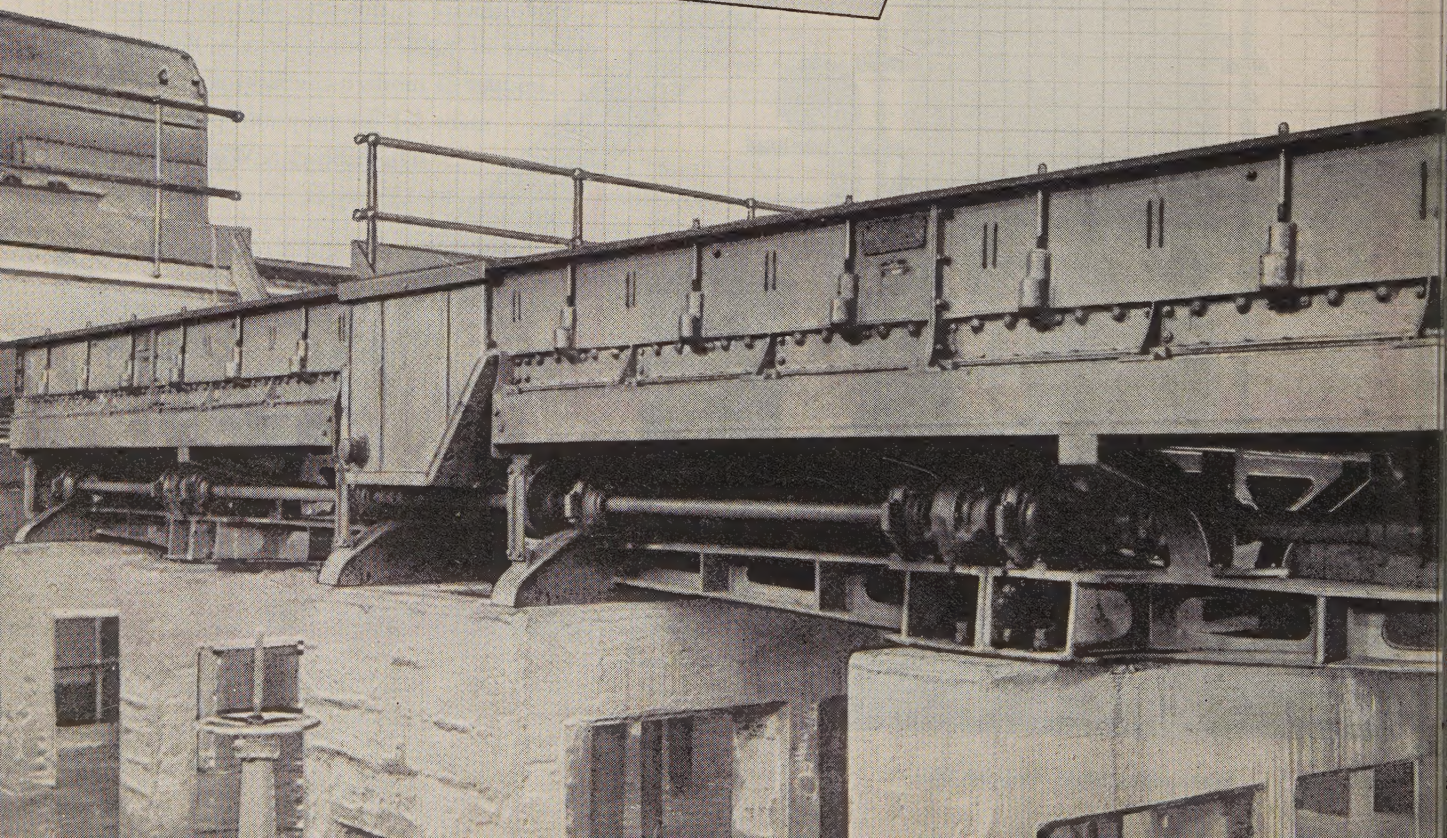

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SOLVAY KNOWS PAPER MAKING . . . its methods . . . its needs . . . and its problems. This knowledge of the paper industry is no mere accident, for SOLVAY has worked closely with paper makers for over fifty years —longer than any other alkali manufacturer!

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Photos courtesy Whippany Paperboard Company, Whippany, N. J.

For fast, on-machine scouring, as low as 2-3-lbs. Syntergent K to 50 gals. water may be used to make up either an acid or an alkaline wash. Felt is run at full width.

FELTS THAT LAST SAVE MONEY, INCREASE OUTPUT

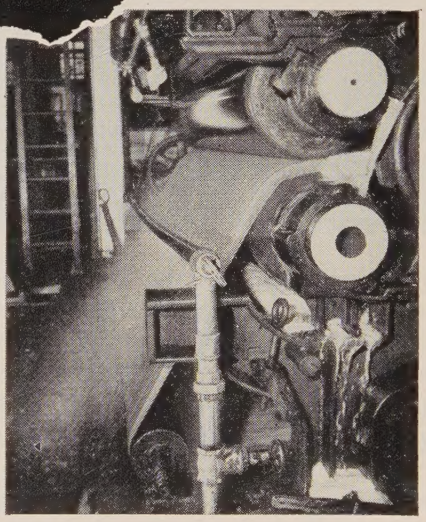
You'll find Nopco Syntergent* K felt washing compound an exceptionally effective felt preserver. We have called upon our wide experience as a leading supplier of textile chemicals, and our close association with the actual problems of producing good felts for the paper maker, to formulate a compound that does an outstanding felt cleaning job . . . that helps to reduce equipment costs and increase production. (Remember: Clean, well cared for felts can actually increase output by as much as 5 per cent.)

Syntergent K mixes readily with warm or cold water in all concentrations, to provide solutions which give copious and persistent lather and have excellent detergent and wetting characteristics. It is stable to both mild alkalis and acids, and thus can be used with either an alkaline or acid wash. It is likewise compatible with soap solutions.

You'll find Syntergent K very effective, also, for wetting out and conditioning brand new felts.

We shall be glad to supply you with formulas for *on*-machine and *off*-machine washing of press felts, wet felts and new felts. Our Technical Service Division stands ready to assist you *in your mill,* to make sure you obtain the best results as economically as possible.

Used in conjunction with soda ash, Syntergent K is ideal for cleaning vats, piping systems and screens during grade changes.



After running felt 10 - 15 minutes, fresh water showers carry away embedded soil in less than 5 minutes. The Syntergent K washes out freely and completely.

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VALUE in Fourdrinier wires is a matter of record... paper quality and production records in mills throughout America reflect the fact that *Appleton Wires are Good Wires!*

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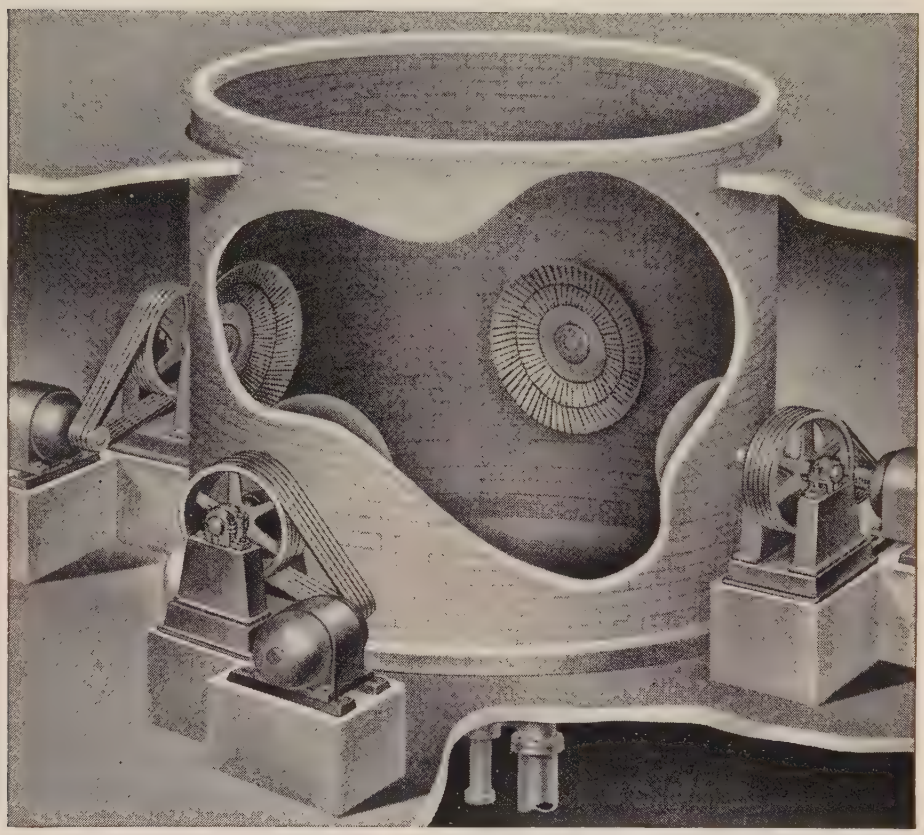
The Rice Barton QuatroPulper

. . . a high production machine . . . ideal for disintegrating pulp, broke or waste paper

Other DynoMachines:

- The **QuatroPulper** is designed for processing stock in large capacities . . . either batch or continuous operation.
- The **DynoChest** is primarily for disintegrating stock in slush form . . . batch operation.
- The **DynoFiner** is for performing the same operation on a continuous basis.



THE stock is charged all at one time into the top of the vat. Four DynoPellers (described below) subject it to the vigorous dynomizing action that completely separates each fibre from its neighbor, maintaining its original length. The simple operating principle and design of the QuatroPulper eliminates the "wracking" and grief of other types of pulpers. Because there are few moving parts there is no loss of production time due to repair or adjustment. The QuatroPulper defibers the stock at low cost and produces a high quality slurry quickly and effectively.

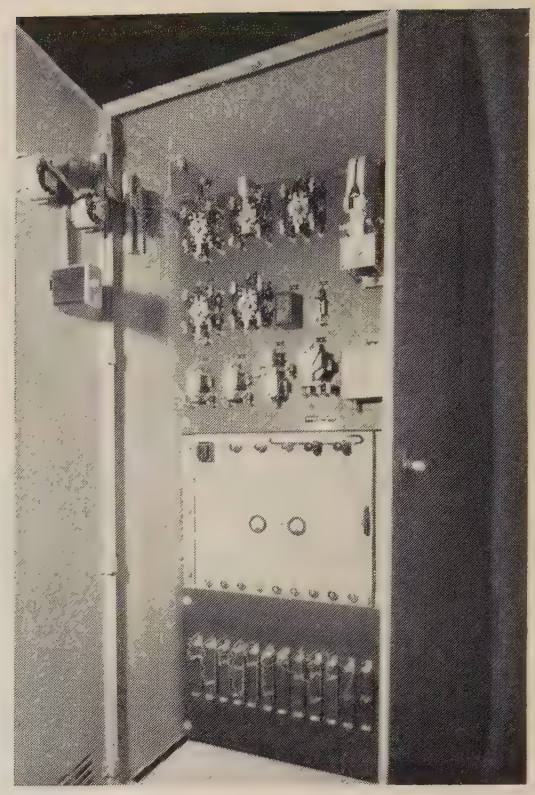
Let us tell you how the QuatroPulper can save YOU *money in processing* YOUR *particular stock. Write today.*

RBR8

The DynoPeller ·····▸ is the heart of all DynoMachines. Its concave face is lined with rough, hard carbide particles. As the DynoPeller rotates it causes a suction at its center that pulls the stock towards it. Centrifugal force then causes the stock to flow rapidly over the rough carbide particles. This effective dynomizing action completely disintegrates the stock . . . separating each fibre from its neighbor while maintaining its original length.

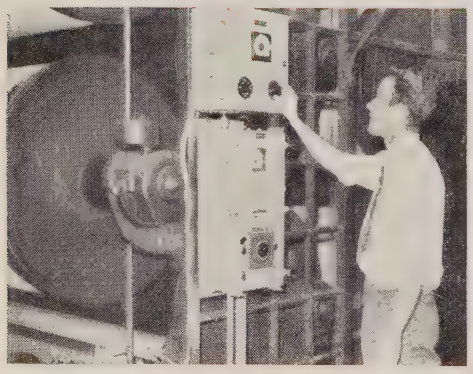
RICE BARTON Research Corporation
WORCESTER 1, MASS.

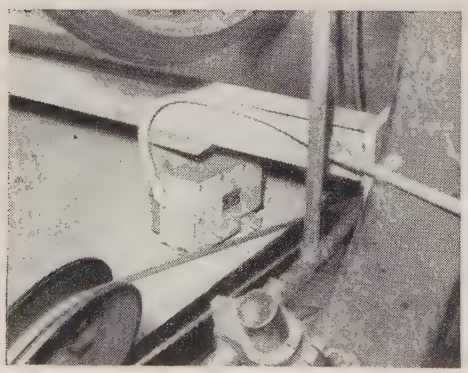
A co-ordinated but independent drive for each paper-machine section is provided by G-E multiple-generator sectional drive, which permits each section to operate at top efficiency with fast, accurate control. Shown here from the dry end is the G-E sectional drive at St. Regis Paper Co. in Tacoma, Wash.



Standardized circuits and simplified wiring in control panels permit faster installation and easier maintenance. Photo shows interior of a typical section control panel which includes electronic pre-amplifier, relays, contactors, and resistors.

Get high production



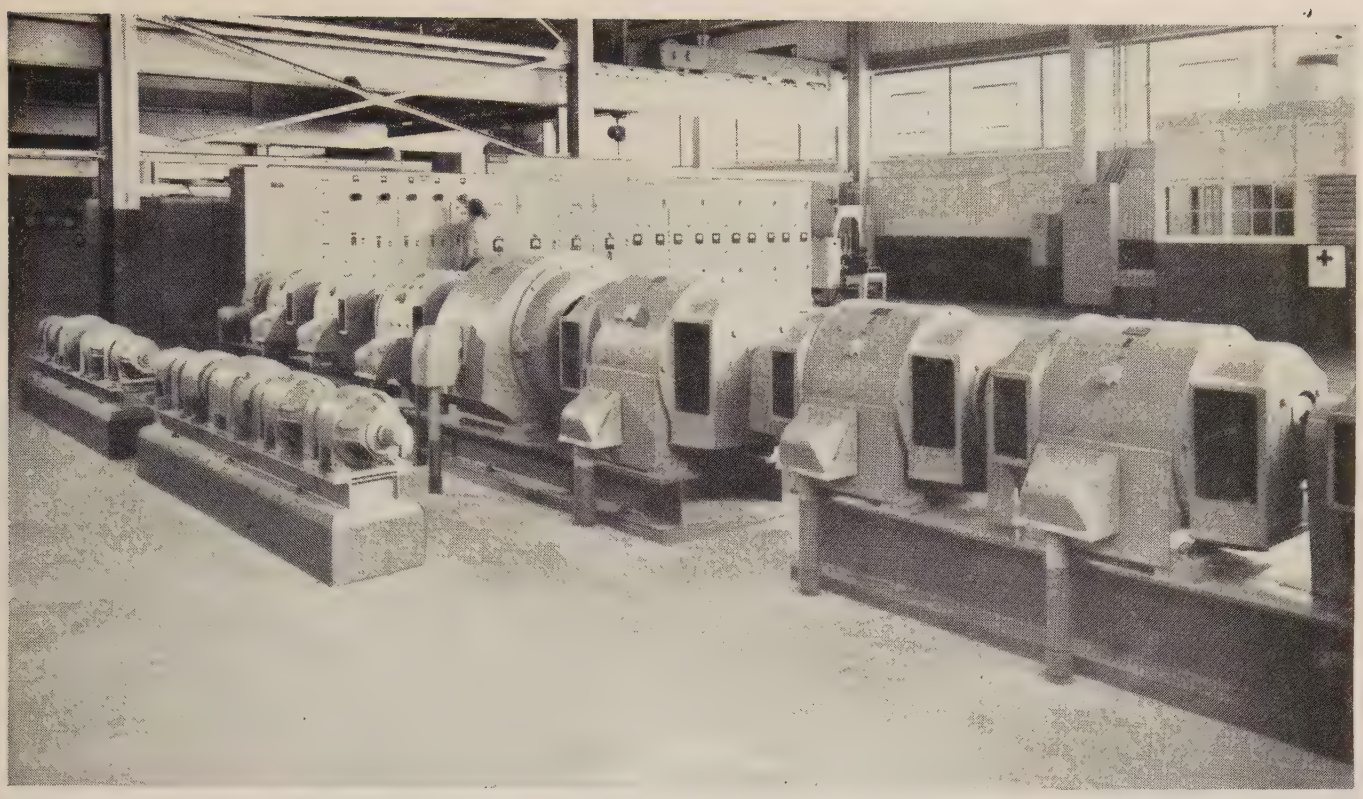


New G-E tensiometer reduces paper breaks, cuts down time!

A revolutionary new development, the G-E paper tensiometer prevents snap-offs caused by excess tension at dryer, calender and reel sections, reduces down time and broke, and helps increase output of uniform-quality rolls. Applicable to new or existing G-E electronic amplidyne sectional drives, it continuously regulates paper tension without damage to the sheet and with greater precision than otherwise possible. Equipment comprises operator's tension controls (top panel in upper photo) and tension head (lower photo). This installation at Ohio Boxboard Co., Rittman, Ohio, was added to an existing G-E drive. When engineered as automatic control into new drive systems, operator's tension controls are combined with the standard section operator's panel. For more data, write for Bulletin GEC-685.

GE

CO-ORDINATED PAPER-MILL DRIVES



Multiple-generator system contributes to easy understanding, simple operation, and quick maintenance. Using a separate generator for each section eliminates the starting generator with its complicated switching that is characteristic of the single-generator system. Shown here, at the Fibreboard Products, Inc., mill at Antioch, Calif., are the G-E amplidyne sets (left) used as exciters for the G-E motor-generator sets (right). The amplidyne, with its fast response and high amplification factor, has been successfully used in over 800 paper-mill applications.

and a uniform sheet!

G-E multiple-generator sectional drive holds draw accurately between sections regardless of load changes—for higher speeds and less broke!

Continuous round-the-clock operation of your paper machine at high speed—to help increase production of uniform-quality paper, paperboard, newsprint or specialty papers—can be yours with a General Electric multiple-generator sectional drive. A growing number of successful installations proves it. And here's why:

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Find out more about this production-boosting drive, representing more than 40 years of experience with the paper industry's specialized needs. Call your G-E representative today, or write for Bulletin GEA-5036. *General Electric Company, Schenectady 5, N. Y.*

GENERAL ELECTRIC

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FREE

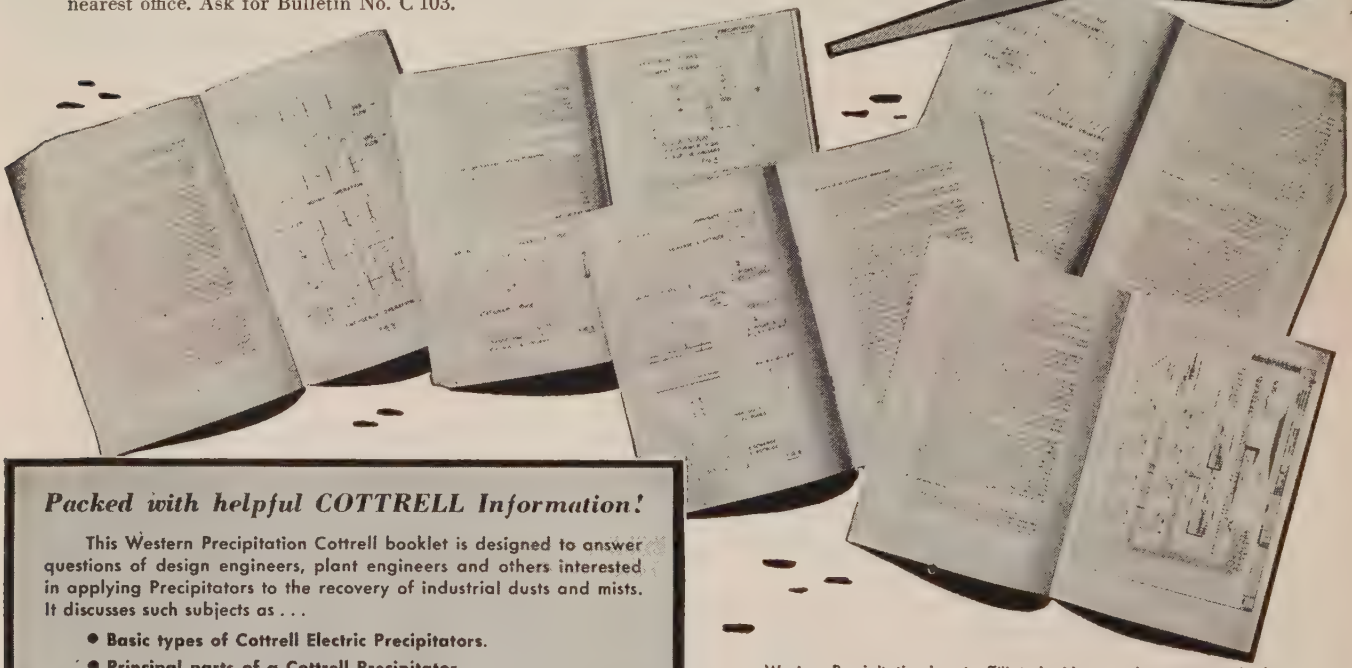
From Western Precipitation—the organization that pioneered the commercial application of Cottrell Precipitation...

IF YOU ARE ENGAGED in any phase of industry where the recovery of dusts, fumes, fly ash, mists, fogs or other suspensions from gases is a problem, you will find this booklet on the COTTRELL Electrical Precipitator helpful and informative.

Western Precipitation pioneered and installed the first commercial application of the well-known COTTRELL Electric Precipitator—Dr. Cottrell, the inventor, being a member of the company. And for more than 42 years Western Precipitation has consistently led in developing new COTTRELL advancements and techniques for recovering suspensions from gases, both wet and dry.

This 28 page booklet summarizes many of the basic facts you should know about modern COTTRELL Precipitators—the various types available, how they operate, principal types of electrode systems and rectifiers, shell constructions, etc. As long as the supply lasts, a free copy will be sent you on request to our nearest office. Ask for Bulletin No. C 103.

28 PAGES
of helpful facts to know about
COTTRELL ELECTRICAL PRECIPITATORS



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- **Principal parts of a Cottrell Precipitator.**
- **Mechanical and Electronic Rectifiers.**
- **Various types of Collecting Electrodes (rod curtains, corrugated plates, dual plates, pocket electrodes, etc.).**
- **Removal of Collected Material.**
- **Factors in Shell Construction (steel, concrete, brick, etc.).**
- **Operating Efficiencies and the Effect of Various Factors on Performance.**

. . . and many other basic Cottrell facts. Write for your free copy of Bulletin C103 today while supplies are adequate!

Western Precipitation is not affiliated with any other company in the field of electrical precipitation except its wholly owned subsidiaries, International Precipitation Corporation and the Precipitation Company of Canada, Ltd. Whether you are now contemplating the installation of a Cottrell Electrical Precipitator, or may be interested in such an installation at a future date, we can and will serve you in *any part* of the United States or other countries.

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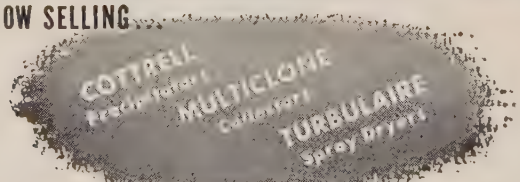

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CHEMIGUM LATEX 245B is a synthetic latex of the nitrile or oil-resistant type—especially developed for use in the beater-impregnation of paper.

CHEMIGUM LATEX 245B is easily incorporated into paper pulp during normal papermaking procedures. There's no need for complicated preparations or revisions of methods—just add the latex as received to the beater after the pulp has been beaten. Coagulation of the rubber particles onto the paper fibers is accomplished by the straightforward addition of alum to the beater. Moreover, the incorporation of CHEMIGUM LATEX 245B does not substantially alter the sheet-making properties of the pulp and the usual methods can be used.

The beater addition of CHEMIGUM LATEX 245B has the advantages of conforming to normal papermaking methods and making possible the production of both light and heavy sheets uniformly impregnated with rubber.

The properties imparted to the paper sheets by impregnation with CHEMIGUM LATEX 245B include greatly improved flexibility, greater elongation and higher edge-tear strength. Latex impregnated papers are particularly adaptable to the manufacture of artificial leather products such as book covers, brief cases, folders, luggage and other specialty items.

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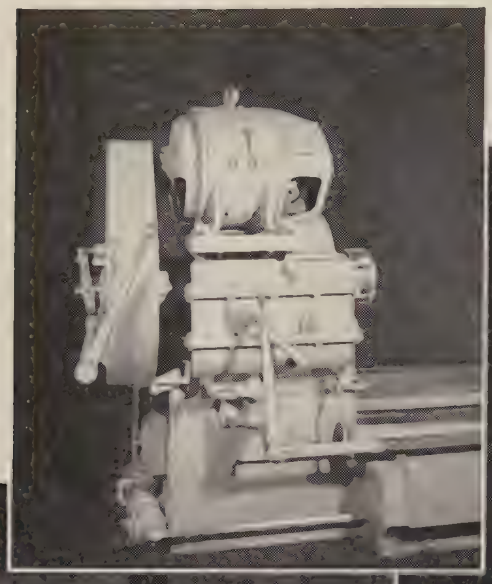

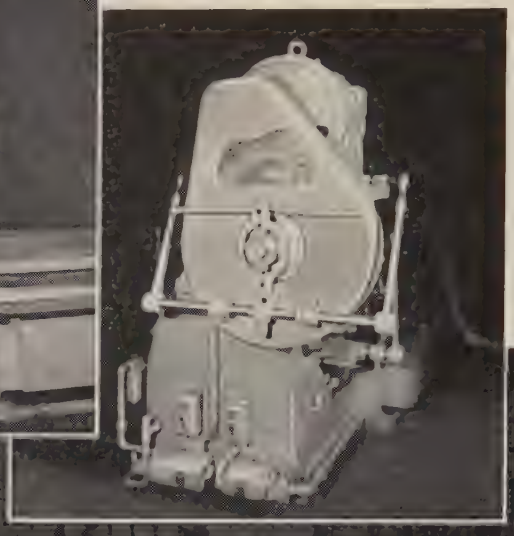

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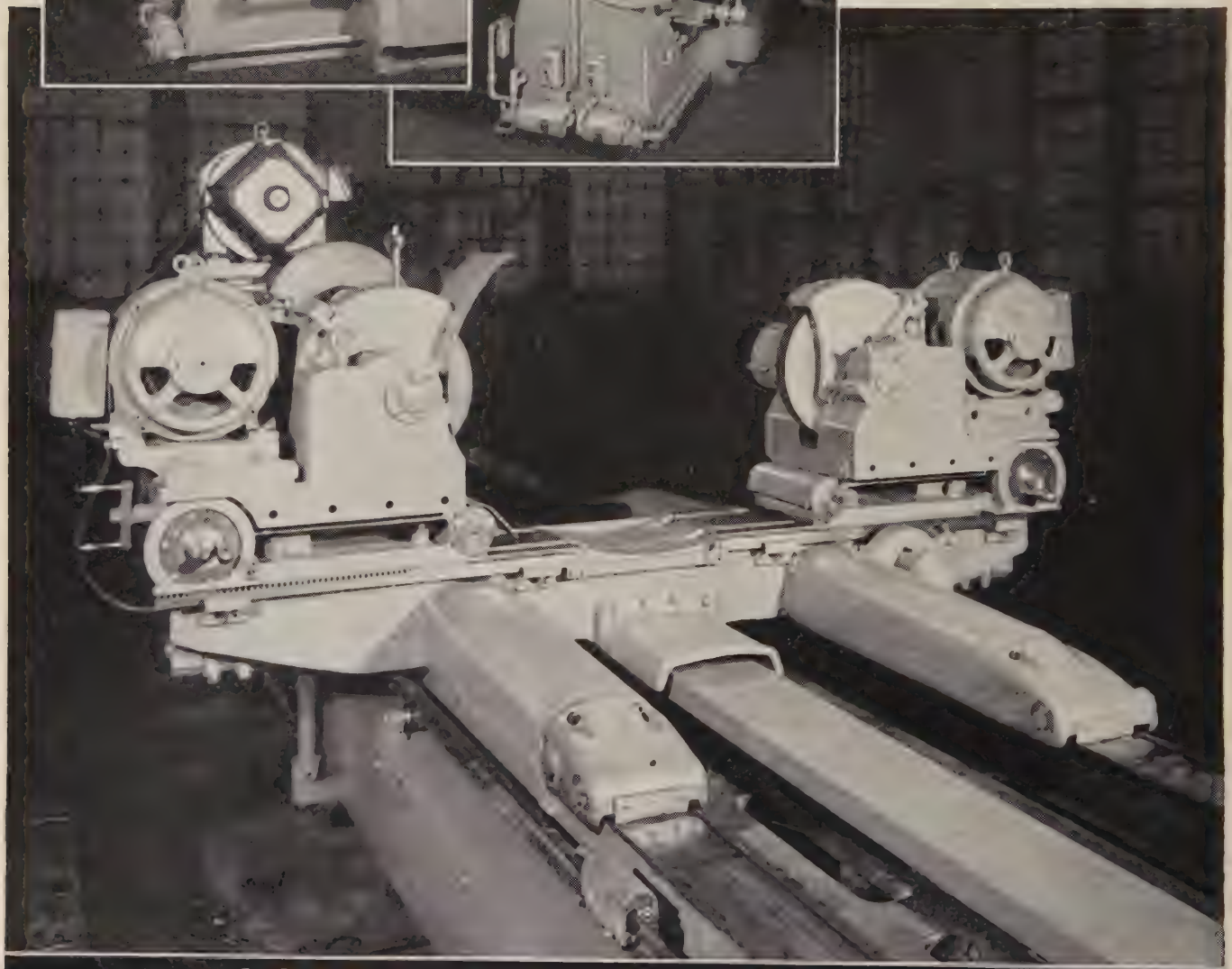

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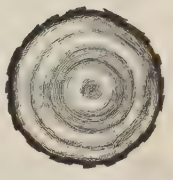

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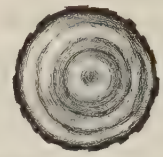

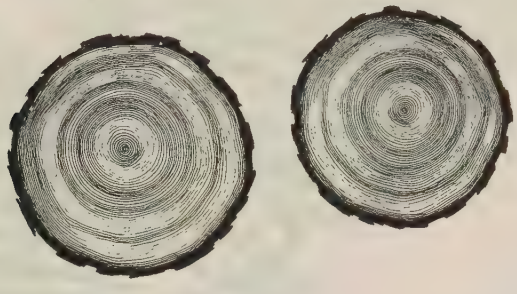

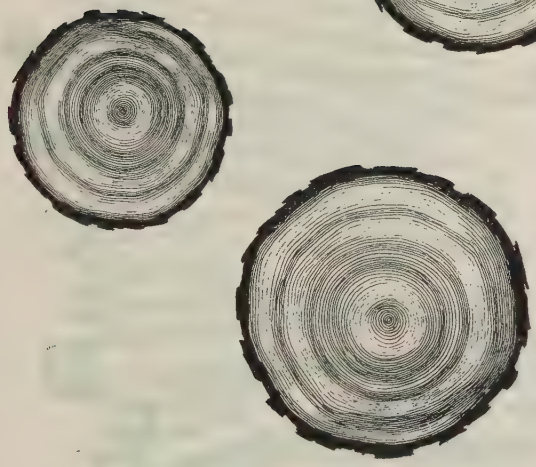

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THE PRESIDENT'S PAGE

When this series of pages was started in the March issue, it was intended that they should be brief but should appear regularly every month. However, circumstances have a way of interfering with the best intentions and those that interrupted this schedule could not have been foreseen nor prevented.

It was planned to address the page in the May issue to the Local Sections; and the following suggestions that would have been timely then are being made rather late. By this time, the Program Committees of most of the Sections have met and have selected the subjects for the meetings during the coming year. Yet, it may not be amiss to make some suggestions as to how this year's activities can be made to tie in with those of the National Organization.

It is realized that the primary responsibility of each Local Section is to its own members, and that their interests and needs should be given first consideration in selecting the subjects of meetings. However, their interests are closely bound to those of the National Association, and a Section can carry on a number of projects that will benefit both its own members and all other members of TAPPI as well.

For example, the Routine Control Methods that were collected by many of the Local Sections will benefit the entire industry for years to come. In spite of all the effects to make these as complete as possible there must be many other quick methods in use by the mills that have been developed recently or that were missed in the first survey.

Collecting these methods should be a continuing project; and it is suggested that each Local Section appoint a Committee on Routine Control Methods that will write to the mills represented in the Section to ask their cooperation in submitting additional methods. If enough new methods are obtained by any one Section, they could be made the subject of a very interesting meeting this season or next. All methods received should be sent to Mr. Macdonald, who will arrange to have them edited and printed on the standardized loose-leaf sheets.

From time to time, all of us have turned to the TAPPI Data Sheets, looking for a table that has never been published. Here is another opportunity for the Local Sections and the National Association to work together for the benefit of all members. A Committee on Data Sheets could question the members of the Section as to what tables are needed and then write Mr. Macdonald who in turn would refer this need to the chairman of the committee that would be in the best position to secure the necessary data. If the Local Section could supply the data also, so much the better.

One of the members of the Executive Committee made an interesting suggestion that is worth passing on. He suggested that an instructive and helpful meeting could be based on various "gadgets" that have been useful in controlling the production and quality in both pulp and papermaking. It sounds like a good idea and one that could well be tried by some of the Local Sections.

A number of Sections have been celebrating anniversaries by means of meetings somewhat more elaborate and on a larger scale than usual, and with special speakers for the occasion. Mr. Macdonald has made it a point to give special publicity to meetings of this kind, calling attention to the time that the Section has been in existence and to the progress that it has made.

During the last few years there has been a tendency for many of the Local Sections to specialize in certain phases of pulp and papermaking and to plan several of their meetings each year to conform with these special interests.

Thus, many of the papers presented at the Pacific Section deal with acid pulping. Undoubtedly, the new Southern Group will specialize in alkaline pulping. The New England Section has had many meetings dealing with the cooking and bleaching of rags. Both the Chicago Section and the new Lake Erie Section have had very strong meetings in connection with the manufacture of containers; and these two Sections have been cooperating closely in this field.

All this is very desirable. Many of our National Committees meet only once a year, and the work between meetings tends to drag. If the activities of a National Committee can be centered in a Local Section, with the rest of the Committee keeping in touch by correspondence, much more will be accomplished. The Committee will make more progress, and the Local Sections will gain from the comments of those members of the Committee who are in other parts of the country, whose views will broaden the outlook and tend to prevent conclusions from being biased by local considerations.

Local Sections who have not yet recognized a field in which their members are particularly interested, might do well to observe closely how their members receive the various subjects covered by their meetings during the year. One that meets with an unusually enthusiastic response could very well merit further consideration and lead to a sustained interest that would carry over from year to year.

Thus, the Local Section can do much to aid the work of the National Association and at the same time benefit from the breadth of outlook that is possible only on a National basis.

K. P. Geohegan
President of TAPPI

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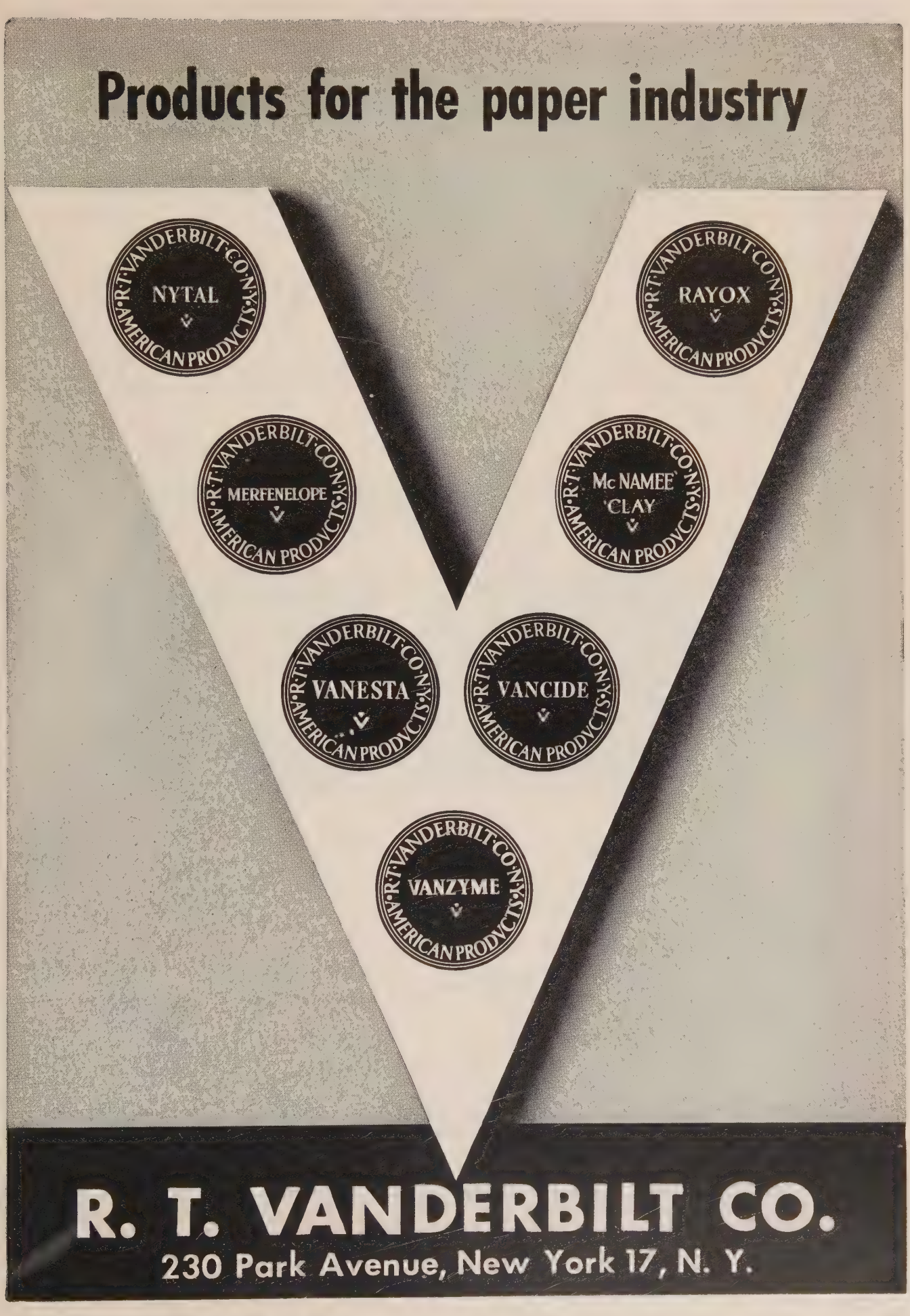

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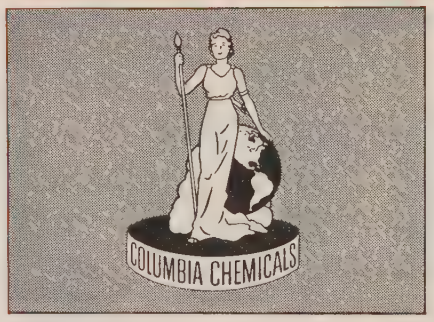

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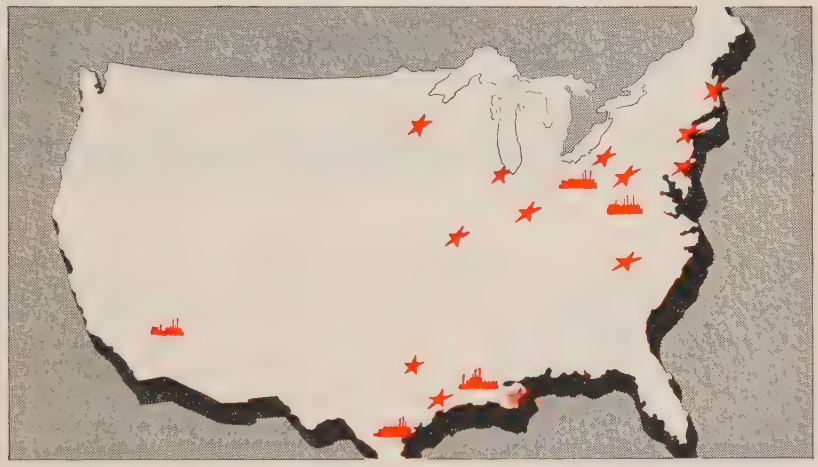

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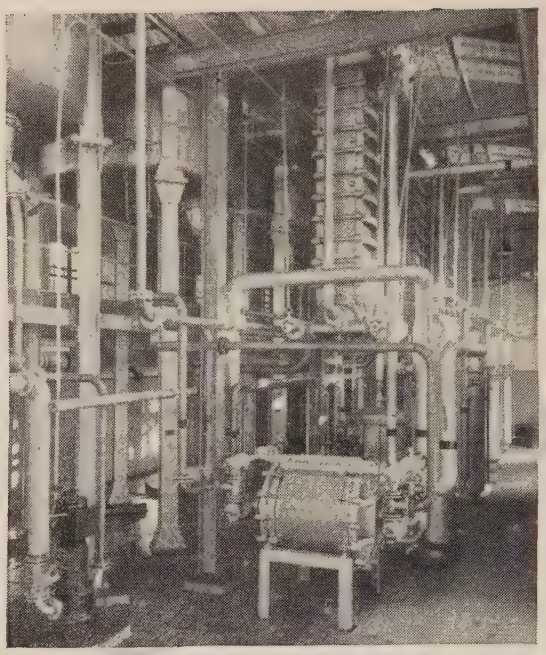

Scandinavian Evaporator installation with Rosenblad* Channel Switching System.

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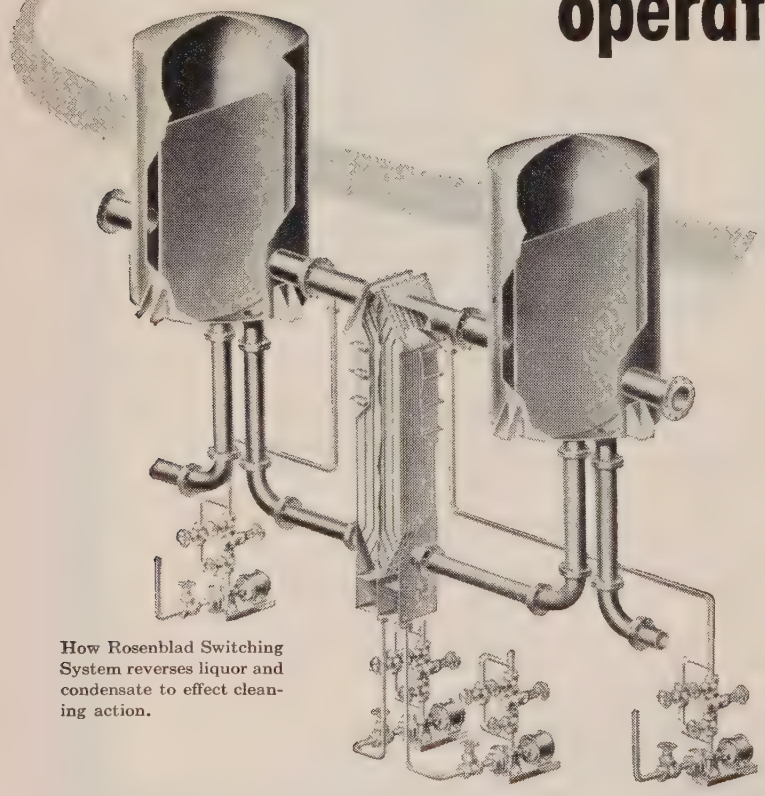

How Rosenblad Switching System reverses liquor and condensate to effect cleaning action.

The Rosenblad Switching System for concentrating sulphite pulp mill waste liquors has been proven in commercial operation—in numerous pulp mills in Scandinavia, some of them in operation over a number of years. These proven installations are now being duplicated in this country by General American. In all of these installations, shut down time and scale removal costs have been eliminated by a condensate wash de-scaling operation carried on during full capacity operation of the evaporator. Surfaces subjected to boiling liquor are periodically switched with those in contact with vapor and condensate to clean heating surfaces during normal continuous operation. All parts of equipment are switched, washing away scale with condensate from pipe lines, valves, vessels—in addition to heating surface. ***Write for Bulletin.***

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Every ounce of Nalco 680 provides active alkaline alumina . . . always available for rapid reaction. That means reduced alum requirements, lower acidity, better sizing, better retention, and therefore, better products.

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"Improvement in sizing, better retention of alumina, and general texture of the sheet using Nalco 680 are very marked. Converter reports the sheet handles better."

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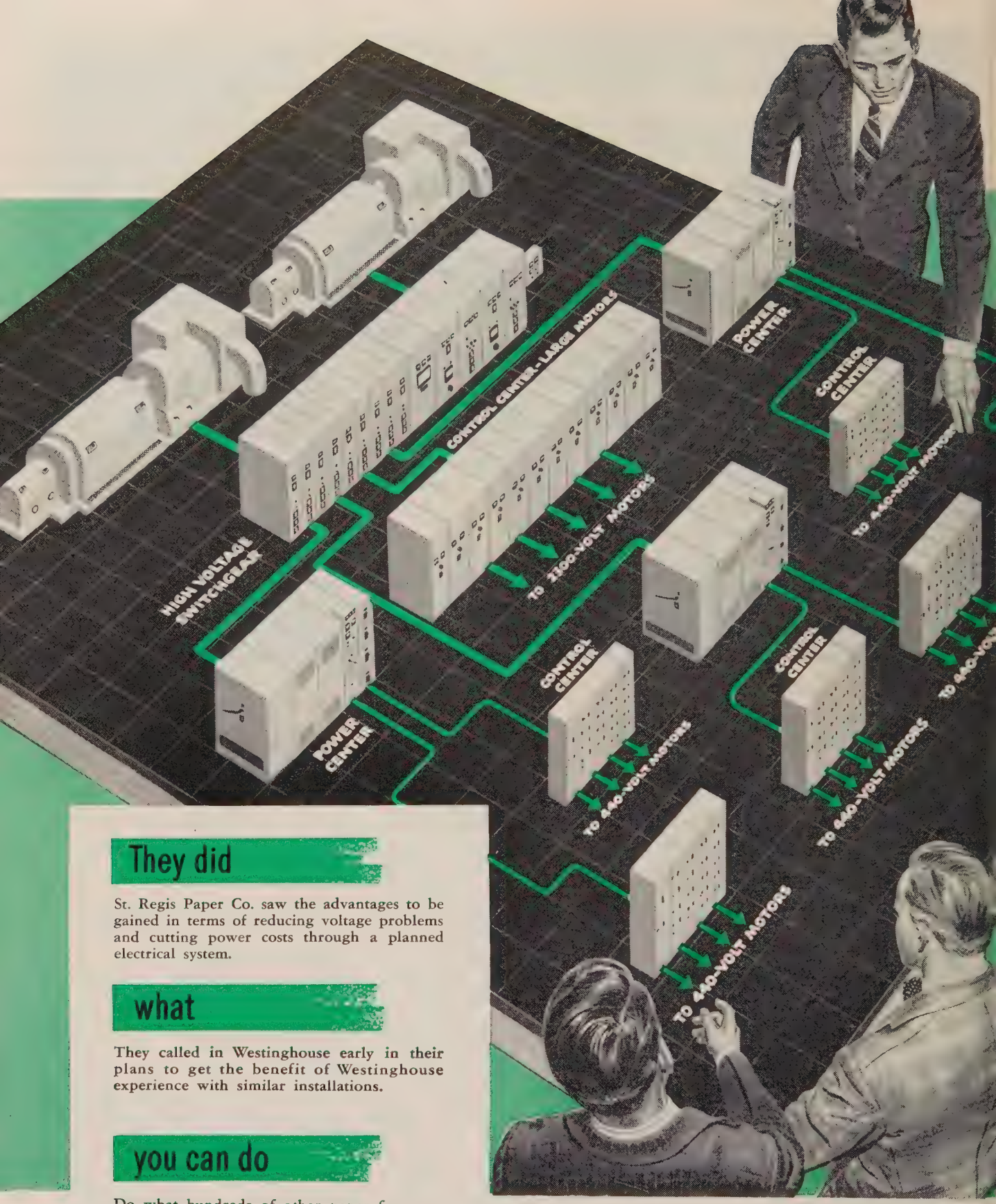

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St. Regis Paper Co. saw the advantages to be gained in terms of reducing voltage problems and cutting power costs through a planned electrical system.

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They called in Westinghouse early in their plans to get the benefit of Westinghouse experience with similar installations.

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Do what hundreds of other paper firms are doing. Have Westinghouse work with your engineers in the application of the best electrical system for your plant.

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Whether it's a modern electrical system like this, a new drive, better servicing or simply the application of a piece of electrical equipment to a tough job — Westinghouse has the answer.

St. Regis Paper Company's moneysaving new power system. Good planning, with help from Westinghouse, resulted in a highly efficient installation.

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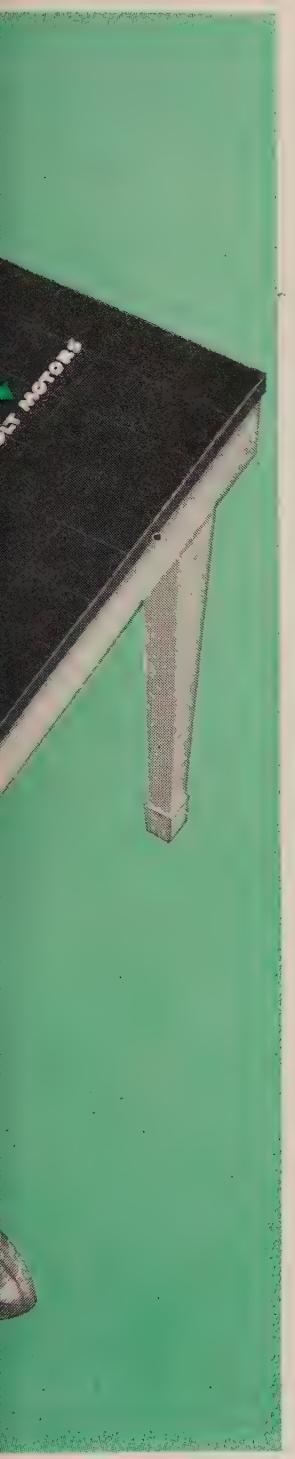

If you're going to build, expand or modernize a paper mill, plan your Power System *early* in the plant design stage. When Alabama Pulp and Paper Company, now a part of St. Regis Paper Company, built a new mill at Pensacola, Florida, they called in Westinghouse early to help plan the system. They're getting benefits that will keep paying off for the life of the mill—and these same benefits can save for you.

No voltage problems—There's no low-voltage trouble to slow production in this new mill. Machines throughout the plant get full voltage from Power Centers located *throughout* the mill. The Power Centers are served by high-voltage feeders from the main generators. There are no long low-voltage lines to cause voltage drop.

Saves power costs—This whole system was planned on an over-all basis and the effect of the motors and other equipment on the power factor was considered. Thus it was possible to arrange the system to maintain a high load power factor. This saves power generating dollars. More savings come from the short low-voltage feeders because power isn't wasted in transmission losses.

Minimum shutdowns—With Power Centers located throughout the mill, the chances of a plant-wide stoppage are greatly reduced. Also, the major circuit breakers are designed so as not to trip on harmless temporary overloads. When a fault does occur, it's cleared fast and service can be speedily restored.

Low installation costs—The major equipment in this system consists of the High-Voltage Switchgear, Power Centers and Motor Control Centers. Westinghouse supplies each as a factory-assembled unit—pre-wired and pre-tested. In this mill, as in any other, this means big savings in installation, wiring and maintenance costs.

Call Westinghouse for System Planning Help

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Freezing of Water in Exposed Pipelines

THOMAS M. RIDDICK, NORMAN L. LINDSAY, and ANTONIO TOMASSI

In 1949 the senior author was retained by an industrial firm to make a water works survey for a proposed pulp mill. The installation required the design of a water filtration plant of 30-m.g.d. capacity with provision for anticipated expansion in the near future to 50 m.g.d. Raw water was to be drawn at a relatively constant rate from an impounding reservoir created by the construction of a dam, the location and elevation of which were predetermined by topographic conditions.

The mill site was situated about $3^1/_2$ miles from the dam, and elevations were such as to necessitate absolute minimum head losses in the transmission lines in order to maintain the required pressure at the mill by gravity. Therefore, the rapid sand type of water filtration plant had to be located at the highest level possible, and overall friction losses in the transmission pipelines were limited to the low value of 15 feet.

Raw water was to be conveyed a short distance from the reservoir to the plant site by a single line. Two 48-inch transmission lines were selected to connect the plant to the mill, one to deliver filtered and the other completely treated water. Complete removal of color and turbidity was required for only half the supply, while filtration alone was adequate for the remainder. Cost estimates showed that the interest and amortization of the dual 48-inch lines (as compared with a single 60-inch line) were much more than offset by the savings effected through elimination of one half the sedimentation basin capacity and reduction by half of the cost of treatment chemicals.

The rock line along the route of the pipe was practically at grade, which precluded placement below ground. Neither was there sufficient fill material economically available for cover. Since the project is located in a cold climate and the long transmission lines were to be exposed, it was necessary to investigate the possibility of freezing in the pipe.

Also, the lines had to be designed for an ultimate capacity of 50 m.g.d. (25 m.g.d. each), whereas flow during the first few years of operation would be only 15 m.g.d. each. This condition further reduced the already low velocity caused by the necessity of limiting head losses in the line, and the low velocities, together with the long length of pipe (16,800 feet), resulted in a detention period of $2^1/_2$ hours at the lower rate of flow. The hazard of freezing was thereby accentuated.

PREVIOUS INVESTIGATIONS

Many pipelines or penstocks of large diameter have been installed in cold climates, and little trouble from icing conditions has been reported where lakes or reservoirs are the source of supply. Practically all such lines, however, are characterized by relatively high velocities and short runs, conditions which are inimical to freezing. The satisfactory performance of these installations is probably responsible for the well-worn, though erroneous, adage, "Running water doesn't freeze." There has been and still is considerable difficulty due to frazil ice in submerged intakes on rivers subject to prolonged freezeovers, and this phase of icing has been subjected to extensive investigation.

Previous experience with either uncovered penstocks or submerged intakes does not, however, provide a basis for evaluating the design and operating conditions of the pipeline under discussion with regard to ice formation, and no installations comparable in terms of length of line, velocity, detention, and temperature conditions can be found in the literature. Communication with several practicing hydroelectric engineers failed to reveal any worth-while precedent or rational method for determining conditions which would result in freezing. Primary investigations, therefore, had to be made, employing fundamental laws of limnology and heat transfer.

The abstract properties of water have been studied over a long period and were competently assembled and reported in 1940 by Dorsey (*1*) of the National Bureau of Standards. The late Howard T. Barnes (*2, 3*) of Canada contributed a life's work on the practical aspects of freezing, and his publications, dating from 1908 to 1928, are outstanding. His investigations, however, dealt principally with frazil and anchor ice formed in large flowing rivers such as the St. Lawrence. Whipple (*4*), Birge (*5*), Welsch (*6*), and others have contributed greatly to the field of limnology and have firmly established the principles governing the temperature variations of reservoir and lake waters. It is only by tying together the works of such investigators and numerous others who formulated the fundamental laws of heat transfer that a rational method can be evolved for evaluating the factors controlling the freezing of water in exposed pipelines. The extensive research on rainmaking and icing of airplanes now under way will undoubtedly add substantially to the existing knowledge of ice formation.

TYPES OF FREEZING

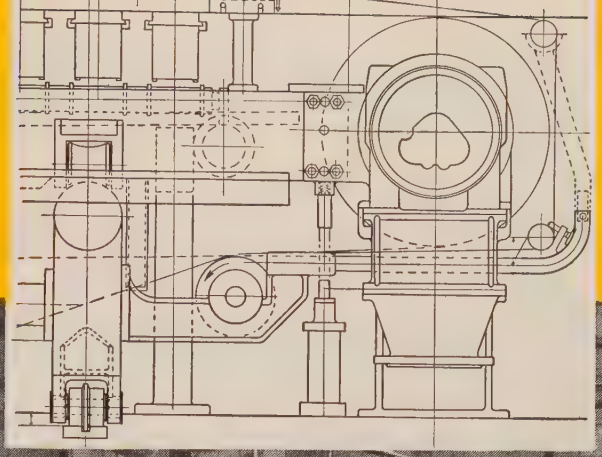
When the temperature of water falls below 32.00°F., freezing may occur in a number of ways. From the standpoint of freezing in exposed pipelines, two types of ice formation are important: frazil ice, which generally forms en masse at temperatures of 31.90 to 31.99°F.; and the creation of solid ice crystals which progressively grow in size and may be formed over a wide range of temperatures below 32.00°F. Supercooling, which is today considered a normal rather than unusual occurrence, can produce either type of ice formation. The variance in the findings of a large number of investigators gives evidence of the unpredictability of results obtained when different (or even the same) types of waters are supercooled.

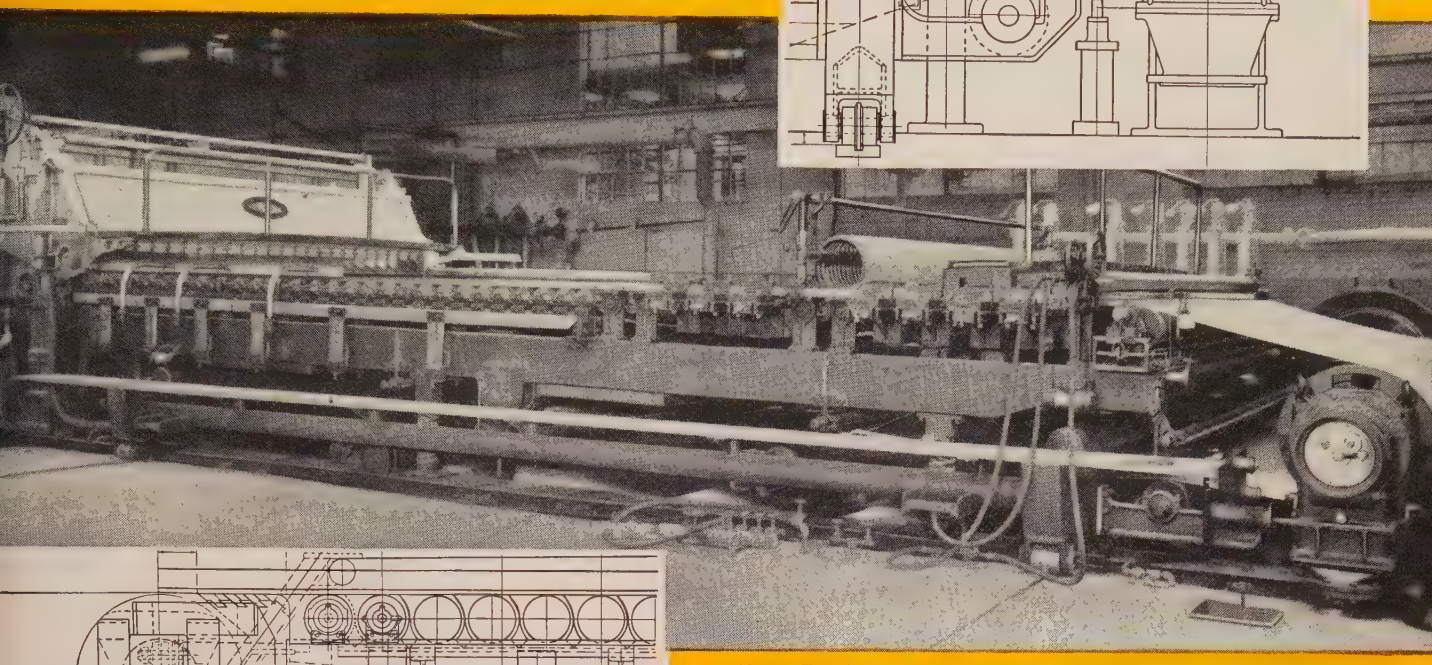
It is well established in both theory and practice that

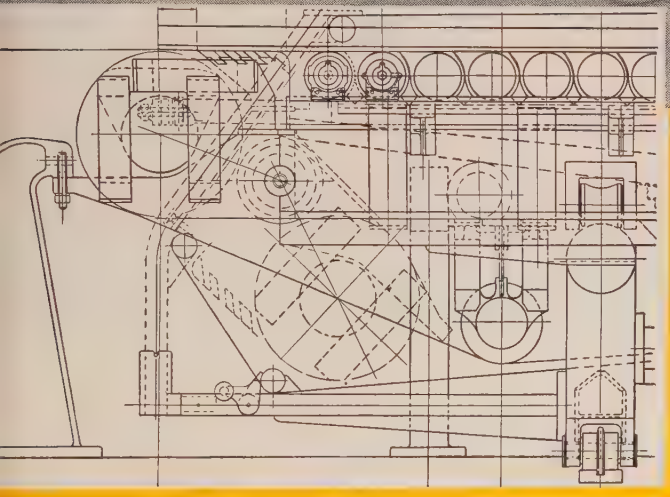
THOMAS M. RIDDICK, NORMAN L. LINDSAY, and ANTONIO TOMASSI, both with Thomas M. Riddick, Cons. Engr. & Chemist, New York, N. Y.

At Right: In the improved "Rapi-Drape" design, the Suction Couch Roll is supported from main Fourdrinier frame as shown. Eliminates need for cantilever jacking arrangement on drive end. Simplifies bearing design and permits use of similar bearings front and back. Eliminates overhung concentrated load on back bearing of suction roll.

Below: Breast Roll is supported from main Fourdrinier frame in the improved "Rapi-Drape" design as shown. Breast Roll, doctor and forming board are raised and lowered as a unit by special hydra-motor. Provides more slack and safer operation when installing new wires. Simplifies and speeds up entire operation.







Above: Fourdrinier Part of "Rapi-Drape" design not including improvements shown in line drawings. Installation at P. H. Glatfelter Co., Spring Grove, Pa.

Improvements IN "RAPI-DRAPE" WIRE HANDLING

Recent changes in the "Rapi-Drape" system have simplified and speeded up the entire wire changing operation.

Suction Couch Roll and Breast Roll are now supported from the main Fourdrinier frame, as illustrated and described above. There is less manhandling. More clearance for draping wires. Less chance of wire becoming wrinkled during installation.

With "Rapi-Drape" Wire Handling, the Fourdrinier remains in perfect alignment, adequately supported at front and back. No danger of deflection stresses and distortion as experienced with complete removal or cantilever change.

"Rapi-Drape" is one of the many design improvements in the new Puseyjones Machines. Write for full details.

"Rapi-Drape" Wire Handling is now being used successfully in these outstanding mills:

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complete freezing of water can only be accomplished after extracting 144 B.t.u. of heat per pound of water when the temperature of the mass has been lowered to 32°F. Also, neglecting the phenomena of supercooling, the total pounds of ice formed at any time is directly proportional to the percentage withdrawal of the 144 B.t.u. required for complete freezing. This factor, together with thermal movement and the insulating effect of thick layers of ice, is largely responsible for the fact that the sheet ice covering a reservoir, lake, or river is seldom more than a few feet in thickness, even in very cold climates.

Before developing a formula to evaluate the conditions which can produce dangerous icing in exposed pipelines, it is advisable to consider further the types of freezing which can occur and to establish whether or not *any* ice formation can be safely tolerated. It is also well to bear in mind the distinction between so-called "pure water" and that collected in quantity from natural watersheds, with or without treatment. Reasonably pure water can be obtained only under the most carefully controlled laboratory conditions. It is necessary to precipitate the entrained dust with flocculent materials such as barium hydroxide and to employ repeated distillations *in vacuo*. Even then, the small percentage of dissolved gases may be partially responsible for the variations encountered in carefully controlled supercooling experiments. At the General Electric Research Laboratory in Schenectady, N. Y., Smith-Johannsen (*7*) demonstrated that "pure water" normally freezes at a temperature of about −20°C. (−4°F.) rather than 0°C. (32°F.), unless the water is in contact with ice crystals.

Natural water, with or without treatment by coagulation and filtration, generally contains calcium and magnesium bicarbonates, sodium and potassium sulphates and nitrates, sodium chloride, silica, the dissolved gases of oxygen, nitrogen, and carbon dioxide, and some organic matter, silt, and algae.

The turbidity due to microscopic particles of silt and algae, even in a filtered water, is generally sufficient—at least in volume, if not in composition—to serve as nuclei

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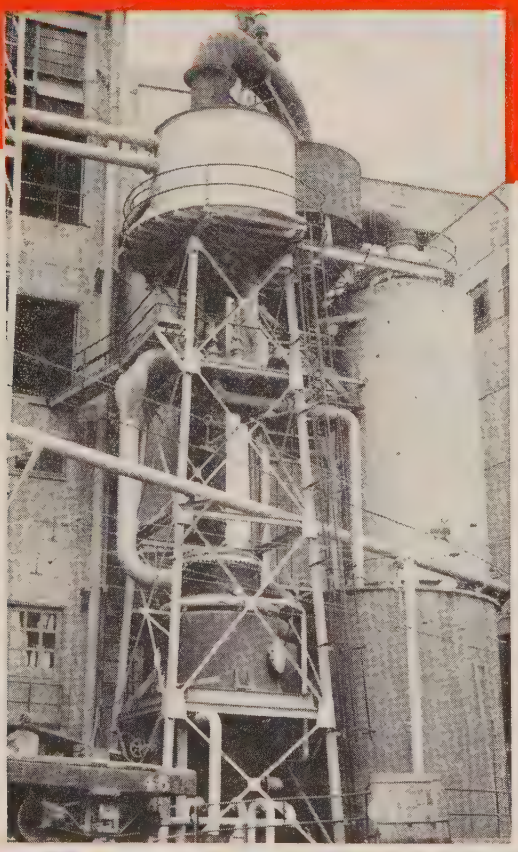

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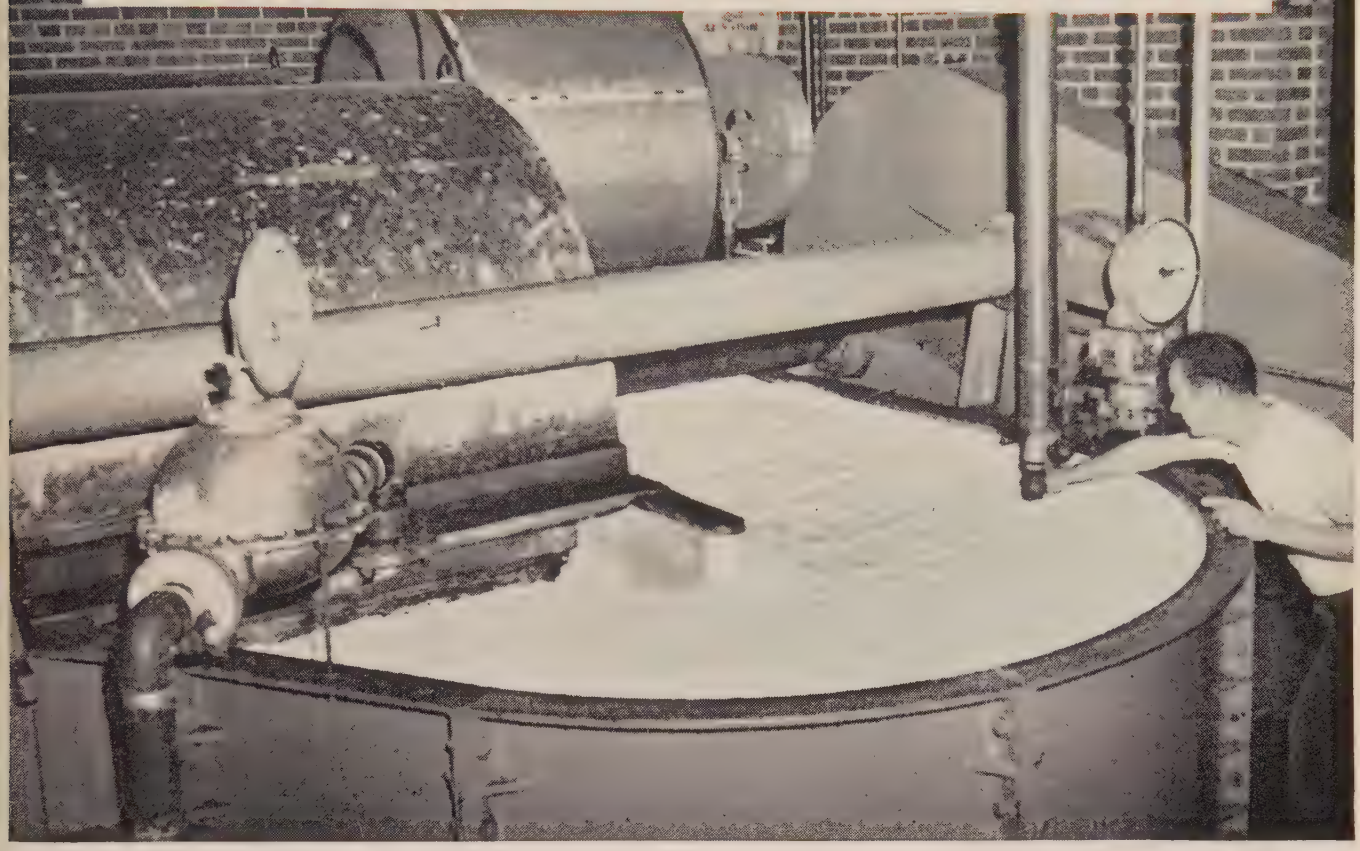

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for ice crystal formation, which precludes supercooling to the degree possible with "pure water." Even raw, unfiltered waters, however, may be supercooled, under conditions of agitation and in vessels with relatively "rough" walls, to as low as 3 to 4°F. below the freezing point, although the temperature at which crystal formation first occurs often seems unpredictable and uncontrollable. This observation is confirmed by laboratory experiments with raw New York City tap water run in connection with this pipe freezing problem.

If ice formation in exposed pipelines could always be relied upon to begin at a fraction of a degree below 32°F. (no appreciable supercooling), if this ice plated out in discrete and growing crystals on the pipe walls, and if these crystals grew inward without exerting any tangential pressure on the pipe walls, then a reasonable amount of ice formation could be safely tolerated. In fact, as will be subsequently shown, some insulating effect would thereby be obtained from the ice itself. Since the shattering stress of ice is approximately 400 p.s.i., even if crystals grew so as to exert full tangential stress on pipe walls, no danger would normally be encountered until more than $^1/_4$-inch thickness of ice had developed. If *no* stress were exerted tangentially, although this seems improbable, a heavy coating of ice could provide a very appreciable insulating effect, and the increase in velocity of the flowing water due to the decrease in effective pipe size would reduce the detention period and protect most lines during severe and attenuated periods of cold weather.

Although the conditions mentioned above are possible, they are the least probable. The most likely method of freezing is the formation of frazil ice, which normally occurs simultaneously in a large mass of water upon supercooling from 0.01 to 0.10°F. The size of these ice particles varies from "microscopic" to about 0.1 mm. in diameter. Because of their small size, they tend to remain uniformly dispersed throughout the mass rather than rising to the surface.

These crystals become readily attached to any roughened surface and would start to build up at a valve, pipe coupling, bend, or welded seam. Additional crystals of frazil ice brought down by the flowing water would then rapidly enlarge this mass and the pipeline would very soon become entirely blocked.

This condition is common in submerged intake lines handling river water at a temperature of 32.00°F. (minus 0.01 to 0.10°F.), but bursting pressures are seldom achieved, because the ice remains in a slushy or coarsely divided state. Such freezing in a pipe exposed to low air temperatures would probably be disastrous, as it would be quite difficult to ascertain the point of stoppage, and the line would probably freeze solid and burst before clearance could be effected.

The author has experienced one such instance which resulted in the bursting of a 16-inch cast-iron main laid above grade. The water in question was drawn from a reservoir at a temperature of 37°F., and an attempt was made to discharge it through cast-iron aerator piping which had been out of service and exposed to subzero temperatures during the previous night. Although the 16-inch control valve was opened manually as quickly as possible, slush or frazil ice formed almost instantaneously in the aerator line and blocked it off completely. Bursting occurred about 4 hours later.

A third and likely method of freezing, which was clearly demonstrated by laboratory experiments with raw water, is the formation of discrete needles and plates of relatively large size after an unpredictable period of supercooling. Although the water used in these experiments contained ample turbidity and algae to serve as nuclei for crystal formation, and the sample (in a cylindrical copper container) was continuously agitated by a mechanical stirrer, supercooling continued for 3 or 4°F., at which point of heat extraction a mass of needle-like crystals formed simultaneously and the temperature rose from 28 to 32.00°F. Ice crystals remained in suspension during the rest of the freeze, with further cooling resulting in the gradual build-up of solid sheet ice on the cylindrical walls of the vessel. But, translated into terms of flow in an exposed pipeline, the effect of these crystals would be to produce a slurrylike mass which would retard the rate of flow of water in the pipe to such an extent that it could not be readily emptied, and clogging of the pipe would probably occur.

A consideration of these methods of freezing indicates that *no* ice formation can be safely tolerated. Therefore, the temperature of water at the discharge end of the pipeline should always be maintained above 32.00° F., and, from a practical standpoint, the safety factor should, if possible, be 0.5°F., although 0.1°F. would actually prevent ice formation.

LIMNOLOGICAL CONSIDERATIONS

There is only one practical method of preventing the freezing of water in pipelines which have long detention periods and are exposed to cold weather: to withdraw "warm" water from the reservoir or lake supply. By warm water is meant water above the freezing point and with a B.t.u. content sufficient to take care of the heat losses which occur along the transmission line.

The science of limnology is well developed as far as temperatures are concerned. Stratification, due to changes in the density of water with changes in temperature, causes bottom waters to deep lakes and reservoirs to approximate closely 4°C. (39°F.). After the freeze-over the waters in the upper stratum or epilimnion will closely approximate a temperature of 32°F. This zone, however, is usually only a few feet in depth during the winter months. The temperature of waters from the lower zone of the thermocline can be safely predicted at 3°C. (37°F.) and that of waters in the bottom zone, at 4°C. (39°F.), as indicated in Fig. 1 which shows thermal stratification in North Temperate and Arctic Zone lakes in Winter. Although these conditions of temperature are basic, they apply primarily to reservoirs and lakes not subject to heavy withdrawal of water or to considerable fluctuations in water levels.

Unlike well-stratified waters, the temperature of the feeder streams, during periods when air temperatures average 10 to 20°F. below freezing, will generally be

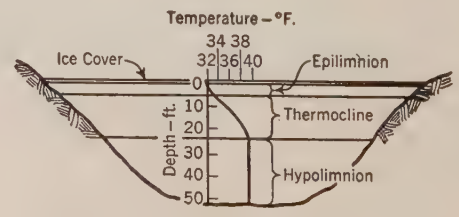

Fig. 1. Thermal stratification

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32.00°F. ± 0.1, and such streams will often carry frazil ice. Because precipitation is mainly retained as ice, snow, or frost on the watershed, runoff during the Winter months is generally light. If a main feeder stream, however, discharges into a reservoir close to the gatehouse or outlet, the stratification value of 38 to 39° F. should be lowered to allow for the shortcircuiting of colder water in the area adjacent to the mouth of the stream. This can be a very important consideration in the proper location of reservoir outlets or gatehouses.

Where it is necessary to employ spray aeration at a water treatment plant during the Winter months, a further lowering of temperature is to be anticipated. Therefore, stream waters can seldom be aerated with spray nozzles if air temperatures are far below freezing since frazil or slush ice will form copiously in the aerating basin.

HEAT INPUT

The heat available to prevent ice formation in exposed pipelines is almost entirely due to the degrees of temperature of water above 32.00°F. This heat credit can be mathematically expressed in terms of B.t.u. per square foot of exposed pipeline per hour:

$$H_1 = \frac{\text{(flow of water, lb. per hr.) (temp. at inlet end, °F. } -32)}{\text{area of exposed pipeline, sq. ft.}}$$

This is equivalent to:

$$H_1 = \frac{1325Q(T_w - 32)}{Dl} \qquad (1)$$

in which H_1 is the B.t.u. per square foot per hour available from the specific heat of the water; Q is rate of flow, in million gallons per day; T_w is the temperature of the water, in degrees Fahrenheit, at the inlet end of the pipeline; l is the length of the pipeline, in thousands of feet; and D is the internal diameter of the pipeline, in inches.

Since minimum temperatures generally occur at night, and cold periods are often characterized by cloudy weather, no radiant-heat gain from sunshine or ground surface can be relied upon. Otherwise, this energy might be appreciable, as is evidenced by promising research now being undertaken in connection with solar heating of houses.

The only other credit (besides applied heat) which can be considered as adding to the heat available to prevent ice formation is the frictional heat generated by the passage of water through the pipeline. This can be expressed as:

$$H_2 = \frac{\text{(flow of water, lb. per hr.) (total friction loss in pipeline, ft.)} \times 0.0154}{\text{area of exposed pipeline, sq. ft.}}$$

This is equivalent to:

$$H_2 = \frac{1.70Qf}{D} \qquad (2)$$

in which H_2 is the B.t.u. per square foot of pipe per hour generated by frictional energy; f is the friction loss, in feet, per 1000 feet of pipe, determined from the Hazen-Williams or some other appropriate formula; and D is the diameter of the pipeline, in inches.

This heat gain is negligible for large-diameter pipe at low velocities but may be quite appreciable for small-diameter lines operating at high velocities. In fact, this frictional energy was responsible for lack of freezing in one 20-inch exposed pipeline operating at about 15-f.p.s. velocity where the source of supply was an open stream conveying water at 32.00°F. In this instance, frazil ice sometimes formed in the stream, but was actually melted in passing through the pipeline.

The sum of H_1 and H_2 represents the total heat expendable in any gravity pipeline to prevent ice formation.

HEAT LOSSES

When a pipeline carrying water is surrounded by colder air, a flow of heat from the water to the atmosphere must occur. There are three barriers to this transfer of heat, and four if the pipe is insulated.

Water Film

The first barrier is the water film. The coefficient, h_f, represents the B.t.u. per square foot per hour transmitted through the thin, slow-moving film of water located around the internal circumference of the pipe wall. A simiplified equation for this condition (*8*), applying to water close to the freezing temperature, is:

$$h_f = \frac{202v^{0.8}}{D^{0.2}} \qquad (3)$$

in which h_f is the B.t.u. per square foot per hour per degree Fahrenheit differential transmitted from the bulk of the water at a temperature of 32°F. through the film of the pipe wall; v is the average velocity of water in the pipeline, in feet per second; and D is the diameter of the pipe, in inches. For convenience, various values of v and D to the required powers are given in Table I.

It is evident from equation (3) that the transfer of heat through the water film is extremely high even with large-diameter pipe at low velocities and increases greatly with small-diameter pipe at high velocities.

Conductivity

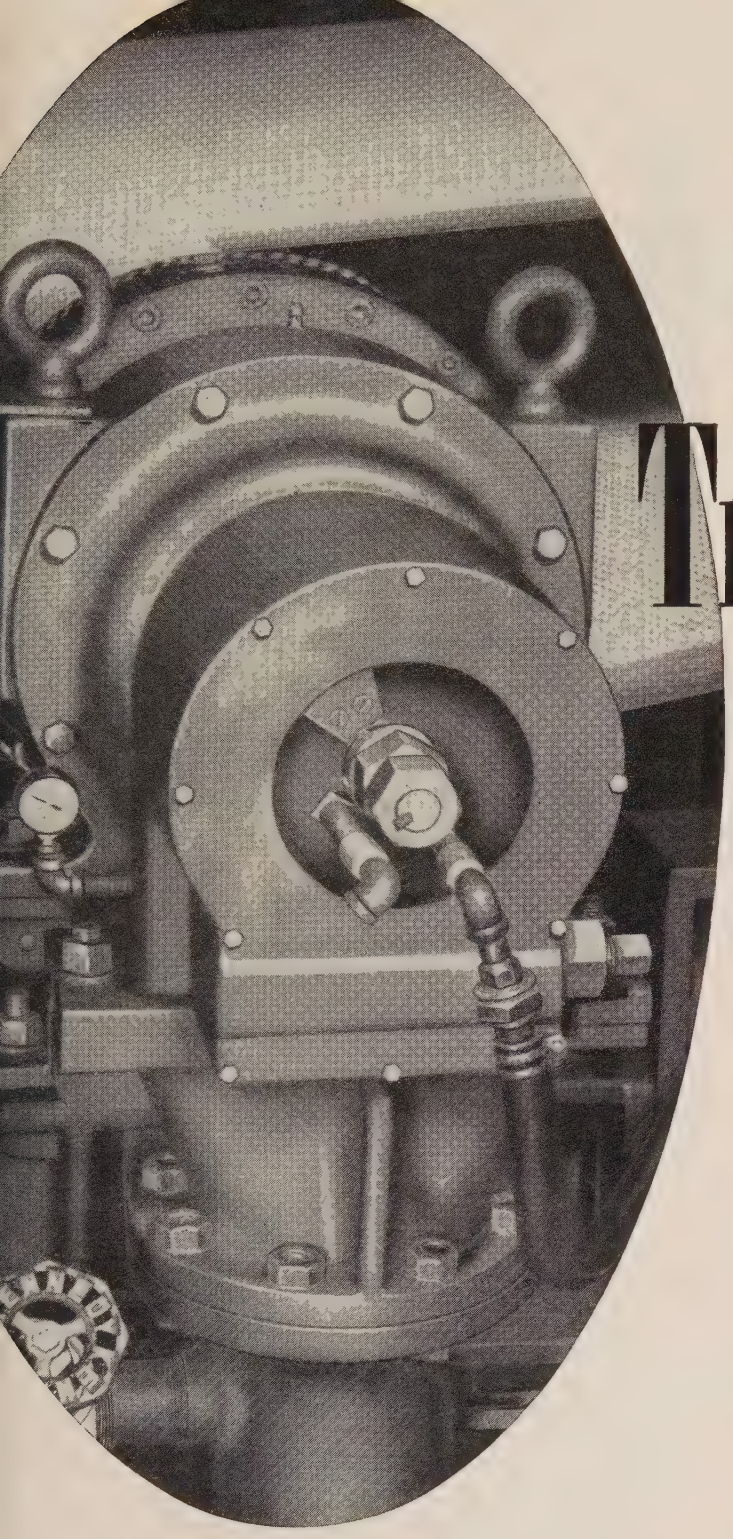
The second resistance to the flow of heat from water to the air is that offered by the pipe material. This depends on the conductivity of the material, the thickness of the pipe wall and the temperature differential between the inside and the outside walls of the pipe. Fourier's law expresses this relationship thus:

$$q = \frac{k\,\Delta t}{L} \qquad (4)$$

in which q is the B.t.u. transmitted by conduction through the pipe wall per square foot of pipe surface per hour; k is the thermal conductivity of the pipe wall in

Table I. Values of D and v

D *pipe diam., in.*	$D^{0.2}$	v *Av. water velocity, f.p.s.*	$V^{0.8}$
6	1.4	1	1.0
12	1.6	2	1.7
18	1.8	3	2.4
24	1.9	4	3.0
36	2.0	5	3.6
48	2.1	6	4.2
60	2.2	8	5.3
72	2.3	10	6.3
84	2.4	12	7.3
96	2.5	14	8.3
		16	9.2
		18	10.1
		20	11.0



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B.t.u. per square foot per hour per degree Fahrenheit per inch thickness of the pipe wall; Δt is the temperature differential, in degrees Fahrenheit (32 minus air temperature, for freezing conditions); and L is the thickness of the pipe wall, in inches.

Therefore, k/L is the rate of heat transmission by conduction per degree Fahrenheit differential through a pipe wall; k'/L' is the corresponding factor for heat conduction through pipe insulating materials, if employed. Values for heat transfer by conduction, for pertinent materials, are given in Table II.

Radiation and Convection

The third and fourth means of liberating heat (from the external pipe walls to the air) are radiation and convection, and the resistive value of these combined losses is referred to as surface resistance. Radiation is the transmission of energy by "heat waves" from the surface of one body to another. Convection is the transmission of heat within a fluid (such as air or water) and, under normal conditions, is caused by changes in the density of the receiving fluid. The relative motion within the fluid may also be produced by mechanical means, such as the agitation of the fluid during heating, or by continued displacement of air (when this is the fluid) due to wind movement.

Both radiation and convection have been subjected to considerable study, and many theoretical and empirical equations have been evolved for their evaluation. The nature of these heat losses, however, often causes widely divergent results between theoretical and actual heat transfers when operating conditions are not comparable with those from which the formula was derived. It is for this reason that radiation and convection are often combined in such computations and that preference is given to empirical data.

The fundamental law of radiation is that expressed by the Stefan-Boltzmann equation, which, in engineering units, may be stated as:

$$H_r = 0.17E\left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right] \qquad (5)$$

in which H_r is the B.t.u. per square foot of radiating surface per hour; E is the emissivity coefficient ranging from 0 (complete reflection) to 1 (complete absorption); and T_1 and T_2 are the absolute temperatures of the radiating bodies, in degrees Fahrenheit.

Table II. Conduction Heat-Transfer Values

Substance	k[a]	*Assumed thickness, in.*	*Heat transfer value, Btu./sq.ft./hr./°F.*
Pipe material			
Steel	420	0.25	1240
Cast iron	385	0.75	515
Concrete	5.3	5.0	1.1
Wood stave	1.0	2.0	0.5
Aluminum	1410	0.25	5640
Asbestos cement	4.5	1.0	4.5
Insulator			
Dry air	0.17	2	0.08
Water	4.0	2	2.0
Ice	15.6	2	7.8
85% magnesia	0.4	2	0.2
"Foamglas"[b]	0.4	2	0.2

[a] B.t.u. per square foot per hour per degree Fahrenheit differential per inch thickness of material.
[b] A product of Pittsburgh Corning Corp., Pittsburgh, Pa.

Table III. Emissivity Factors

Material	*Emissivity factor E*
Asphaltic paint (black)	0.9
White enamel	0.9
Aluminum paint	0.4
Cast iron	0.7
Wood (dressed)	0.9
Asbestos cement	0.9
Aluminum	0.1
Brass or copper (with patina)	0.5

In this problem, $T_1 = 492°$ for water and $T_2 = 455°$ for air, and equation (5) for unit temperature differential (but for full temperature differential conditions) becomes:

$$\frac{H_r}{\Delta t} = h_r = 0.17E\,\frac{(492/100)^4 - (455/100)^4}{37} \qquad (6)$$

$$= 0.77E \text{ B.t.u./sq. ft./hr./°F. differential}$$

Factors of emissivity for computing radiation from the various pipe metals and coatings at a temperature of about 32°F. are approximately as given in Table III.

Convection losses are a function of the temperature differential and the size of the pipeline. A simplified equation applying to horizontal pipe in still air is given by McAdams (*8*):

$$h_c = 0.55\left(\frac{\Delta t}{D}\right)^{0.25} \qquad (7)$$

in which h_c is the B.t.u. transmitted by convection per square foot per hour per degree Fahrenheit differential; Δt is the temperature differential between the outside pipe wall and the air; and D is the diameter of the pipeline, in inches.

Convection losses increase very appreciably with wind velocity, and Langmuir (*9*) gives the following formula to express this relation:

$$h_{cv} = h_c\sqrt{\frac{V + 0.8}{0.8}} \qquad (8)$$

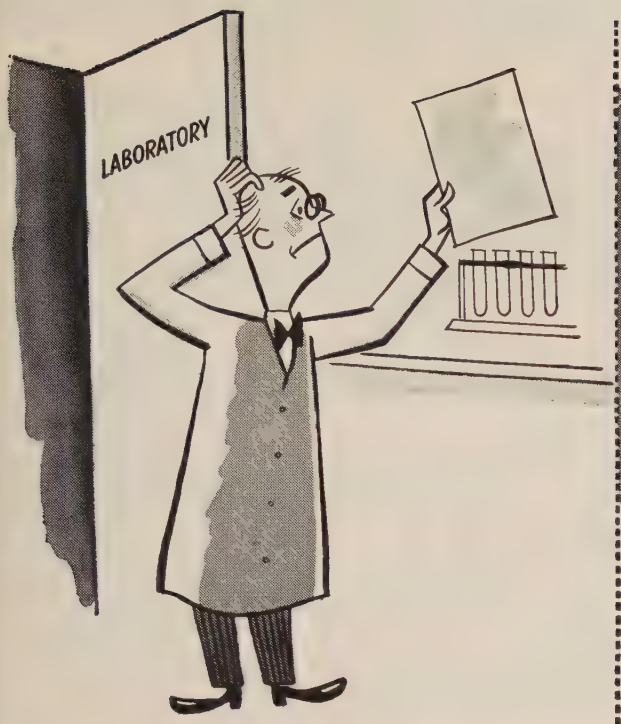
in which h_{cv} represents the convection losses (as above), corrected for wind velocity, and V is the wind velocity, in miles per hour. The factor by which convection losses in still air must be multiplied for different wind velocities is given in Table IV.

Both radiation and convection formulas can be solved when the temperature of the outer pipe surface during balanced conditions of heat exchange is known. When thin-walled and very highly conductive pipe materials such as steel are employed, it is reasonable to assume that this temperature (T_1) approximates the temperature of the water in the pipeline, the lower limit of which is 32.00°F. (or 492°F. absolute).

When pipe walls are thick and relatively nonconductive (as for concrete), the exterior surface will be closer

Table IV. Wind Velocity Factors

Wind velocity, m.p.h.	*Factor* $\sqrt{\frac{V + 0.8}{0.8}}$
5	2.7
10	3.7
20	5.1
30	6.2
40	7.1



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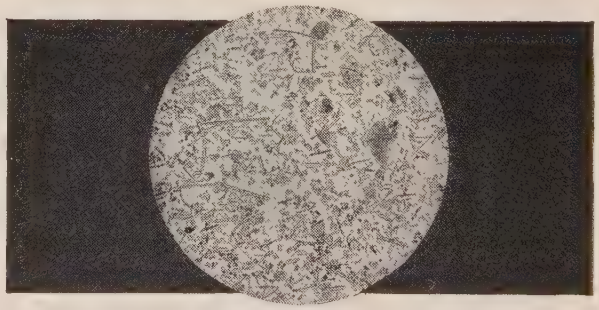

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Table V. Recapitulation of Heat Balance Factors

Terminology and required data

Symbol	Meaning	Unit	Symbol	Meaning	Unit
	Climatological			Pipeline	
T_w	water temp. at pipe inlet	°F.	v	velocity	f.p.s.
T_1	water freezing temp.	°F. abs. = 492	C	friction coefficient[c]	
T_2	air temp.	°F. abs.[a]	f	friction loss[c]	ft./1000 ft.
Δt	temp. differential between and and water ($T_1 - T_2$)	°F.	l	length	1000 ft.
			L	wall thickness	in.
			L'	insulation thickness	in.
V	wind velocity	m.p.h.	k	pipe wall thermal conductivity coefficient	B.t.u./sq. ft./hr./°F./in.
			k'	insulation thermal conductivity coefficient	B.t.u./sq. ft./hr./°F./in.
	Pipeline				
Q	flow rate	m.g.d.	E	emissivity (pipe wall, insulation)	
D	diameter[b]	in.			

Heat-loss factors

Factor	Heat transfer[d]
$h_r = \frac{0.17E}{\Delta t}\left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right]$	by radiation
$h_{cv} = \sqrt{\frac{V + 0.8}{0.8}}\left[0.55\left(\frac{\Delta t}{D}\right)^{0.25}\right]$	by convection
k'/L'	by conduction (through insulation)
k/L	by conduction (through pipe wall)
$h_f = \frac{202v^{0.8}}{D^{0.2}}$	through water film

Heat-input factors

Factor	Description
$H_1 = \frac{1325Q(T_w - 32)}{Dl}$	heat available due to temp. of water above 32°F.
$H_2 = \frac{1.70Qf}{D}$	heat generated by friction

[a] Inside diameter for thin walls; average diameter for thick walls.
[b] Hazen-Williams formula.
[c] Equals 460 plus air temperature in degrees Fahrenheit.
[d] Per degree Fahrenheit differential.

to the temperature of the surrounding air. Resistance to conduction rather than to convection and radiation will then be the main factor governing heat transfer. Under such conditions, radiation and convection losses are smaller than those given by equations 6 and 7, which are based upon the full temperature differential. Divergency, however, is on the side of safety and is not appreciable, since the range of temperature for this problem is restricted. Exact values could be determined by a trial-and-error procedure, but this high degree of accuracy is unwarranted.

APPLICATION OF PRINCIPLES

The consideration of each significant step of heat gain and heat loss in exposed pipelines now enables the inclusion of all of them in a single formula to express each of these quantities. The various factors are recapitulated in Table V, together with a listing of terminology and required data, and are shown diagrammatically in Fig. 2.

The heat available to prevent freezing is:

$$H_{\text{input}} = \frac{Q}{D}\left[\frac{1325(T_w - 32)}{l} + 1.7f\right] \qquad (9)$$

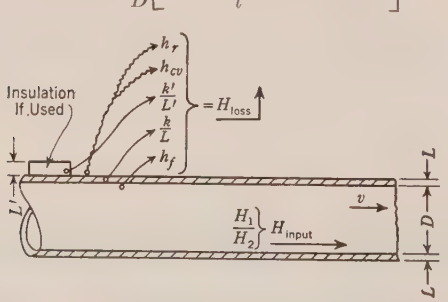

Fig. 2. Heat balance in exposed pipelines

The heat losses can be expressed as:

$$H_{\text{loss}} = \frac{\Delta t}{\frac{1}{h_f} + \frac{L}{k} + \frac{L'}{k'} + \frac{1}{h_r + h_{cv}}} \qquad (10)$$

in which the term L'/k' is the resistance of insulating material (if used) of thickness L' and thermal conductivity coefficient k'. It will be noted that convection and radiation are expressed as a joint unit, which then combines in series with the other resistances.

To prevent freezing, the heat input must be greater than or equal to the heat losses, and a factor of safety is highly desirable.

In the pipeline under discussion, the pertinent data are as follows: $Q = 25$ m.g.d.; $T_w = 35$°F.; $D = 48$ in.; $T_{\text{air}} = -5$°F.; $v = 3.1$ f.p.s.; $f = 0.60$ feet/1000 feet (at $C = 130$); $l = 16.8$; $\Delta t = 37$°F.; and $V = 35$ m.p.h. The pipe materials considered were steel, wood stave, concrete, and aluminum. The heat input in all instances was:

$$H_{\text{input}} = \frac{25}{48}\left[\frac{1325(35-32)}{16.8} + (1.7)(0.6)\right]$$
$$= 0.52\ [237 + 1.0]$$
$$= 124 \text{ B.t.u./sq. ft./hr.}$$

It is evident that, in this pipeline, the gain in heat due to frictional resistance was negligible.

Heat-loss coefficients for film resistance and convection from thin-walled metals are independent of pipe materials, hence common for all instances. These values are:

$$\frac{1}{h_f} = \frac{1}{202(3.1)^{0.8}/48^{0.2}} = \frac{1}{500/2.2} = 0.0044$$
$$h_{cv} = 6.6h_c = 6.6 \times 0.55(37/48)^{0.25}$$
$$= 6.6 \times 0.55 \times 0.94 = 3.4$$

Computations of conduction and radiation for $^1/_4$-inch

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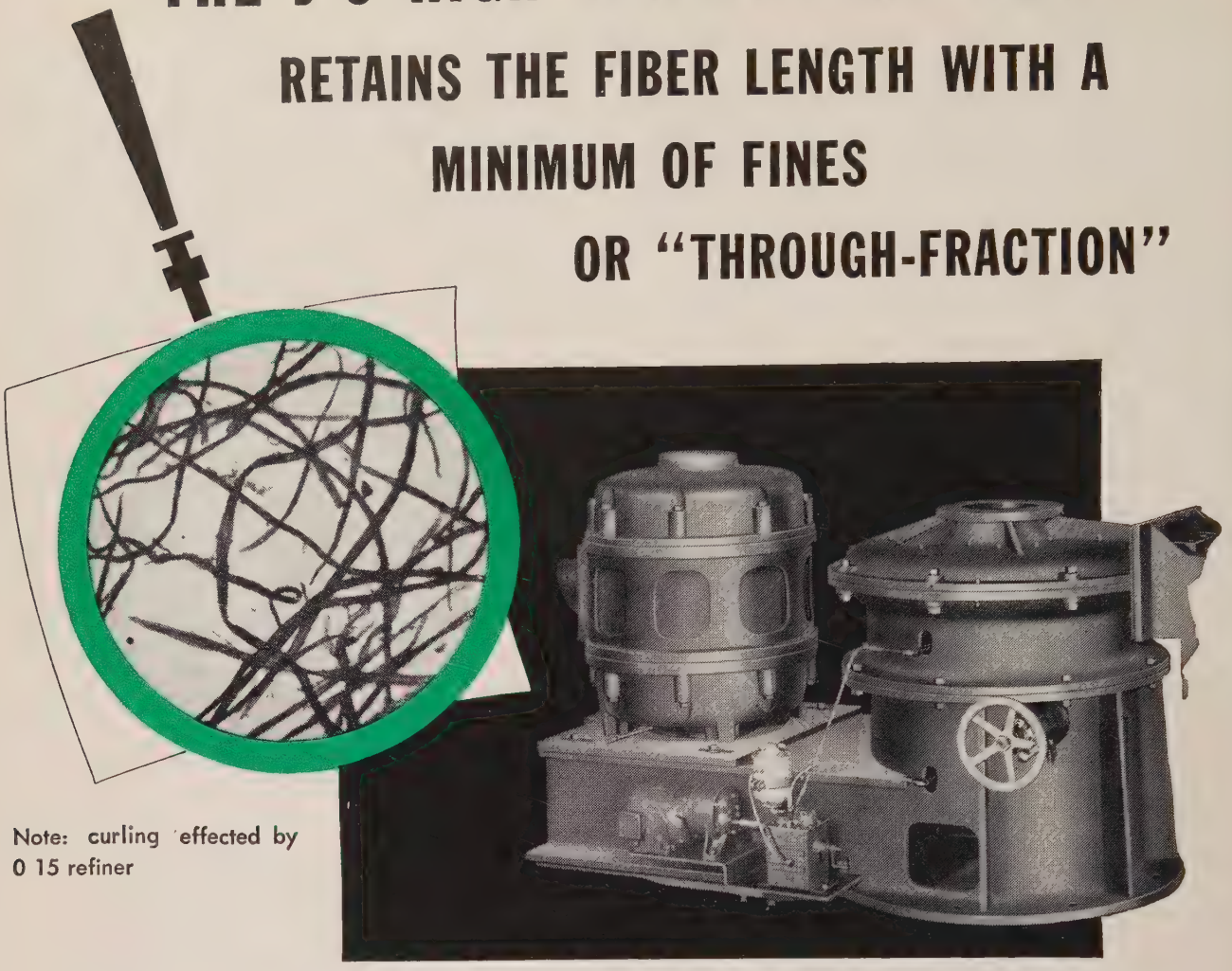

Note: curling effected by 0 15 refiner

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steel pipe, where $k = 420$ and emissivity $(E) = 0.7$, are as follows:

$$\frac{L}{k} = \frac{0.25}{420} = 0.0006$$
$$h_r = 0.7 \times 0.77 = 0.5$$

Radiation and convection losses are then combined:

$$h_{cv} + h_r = 3.4 + 0.5 = 3.9$$
$$\frac{1}{h_{cv} + h_r} = \frac{1}{3.9} = 0.26$$

The combined over-all heat losses are therefore:

$$H_{loss} = \frac{37}{0.0044 + 0.0006 + 0.26} = \frac{37}{0.26}$$
$$= 142 \text{ B.t.u./sq. ft./hr.}$$

These computations indicate that this 48-inch steel pipeline, at a rate of flow of 25 m.g.d., would have no safety factor against freezing near its end, as the available B.t.u. amounts to 124 per square foot per hour, against heat losses of 142. Under operating conditions of 15 instead of 25 m.g.d. during the first few years of service, the available B.t.u. would be reduced to approximately 15/25 of 124, or 75 B.t.u. per square foot per hour. This, of course, means that the freezing point would be reached at about midlength of the line.

It is also evident, from an analysis of resistances to the various heat losses, that water film and steel pipe material afford no appreciable retardation to the flow of heat, and that convection and radiation are the sole controlling factors. This result substantiates the assumption that, with thin-walled metal pipe, the exterior wall temperature would approximate the water temperature, thus obtaining the full temperature differential of 37°F.

A study of the formula for heat loss shows that conduction resistance is the only factor subject to wide variations and depends upon the thickness and thermal conductivity of the material employed. For a 5-inch concrete pipeline, for instance:

$$k = 5.3; \quad \frac{L}{k} = \frac{5}{5.3} = 0.95$$

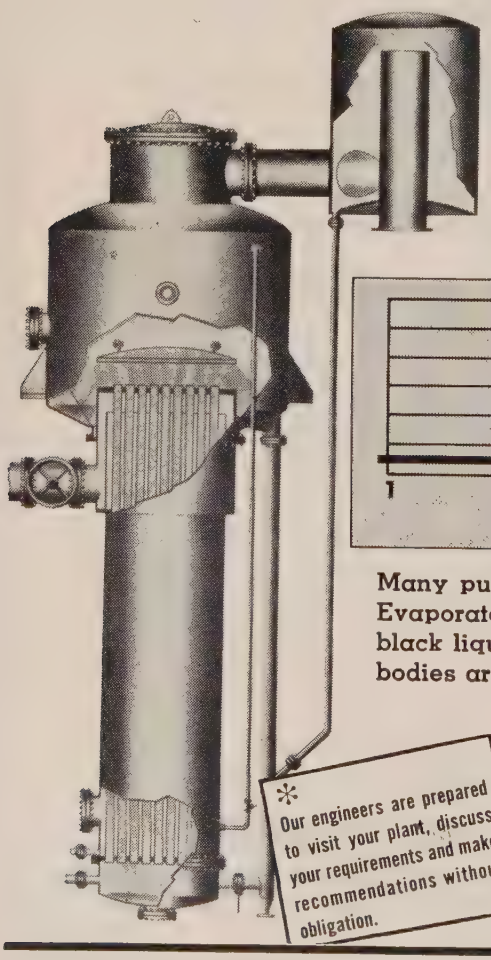
Assuming that combined convection and radiation losses are the same as for steel pipe:

$$H_{loss} = \frac{37}{0.0044 + 0.95 + 0.26} = \frac{37}{1.21}$$
$$= 30 \text{ B.t.u./sq. ft./hr.}$$

This value is much below the heat input for the 25-m.g.d. rate (124 B.t.u.) and also well below the heat input for the 15-m.g.d. rate (75 B.t.u.). Concrete pipelines would, therefore, provide a substantial factor of safety. The same is true for 2-inch wood-stave pipe, where the heat losses would be:

$$k = 1.0; \quad \frac{L}{k} = \frac{2}{1} = 2$$
$$H_{loss} = \frac{37}{0.0044 + 2.0 + 0.26}$$
$$= 16 \text{ B.t.u./sq. ft./hr.}$$

The widespread use of wood-stave pipe is no doubt responsible for the absence of operating difficulties due to freezing in numerous long and exposed pipelines located in cold climates. It is probably true, however,



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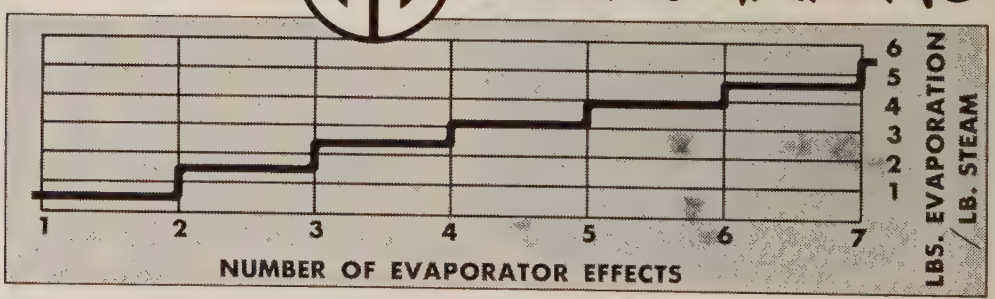

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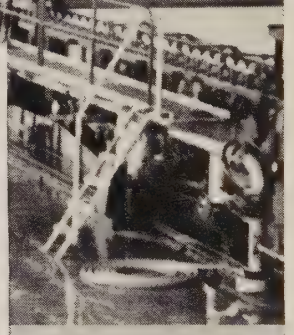
View showing the ROSS roof heating and ventilating system, and 302 ft. long ROSS removable panel machine hood at Natchez.



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that many such lines operate on a very narrow margin of safety, and one notable example of freezing in an exposed 8-mile section of 28-inch wood-stave pipe has been recorded (*10*).

The formula also seems to offer an explanation for an apparently incongruous condition noted in Canada. In this instance, water at a temperature of about 39°F. during the winter months was discharged from the bottom of a lake to an open stream. After a short traverse of the stream bed it was diverted to a covered wood flume about 1 mile long, where the water temperatures sometimes decreased to 32°F. or below, with the formation of frazil ice. From the flume, the water passed through a mile of 20-inch steel pipe laid at a very steep slope, where the flow velocity was extremely high. Operating data during critical periods were approximately as follows: $Q = 20$; $v = 15$ f.p.s.; f (at $C = 100$) $= 45$; $T_w = 32.0$; and $l = 5$. The heat available to prevent freezing of the line was, therefore, due only to that generated by friction, or

$$H_{\text{input}} = \frac{20}{20}\left[\frac{1325(32 - 32)}{5} + 1.7 \times 45\right]$$
$$= 1[0 + 77]$$
$$= 77 \text{ B.t.u./sq. ft./hr.}$$

Since there was no further freezing in the line and sometimes a melting of frazil ice, it seems evident that the heat gain due to friction exceeded the combined heat losses.

TEMPERATURES

In the problem of the freezing of the dual 48-inch pipelines, temperature records were available for a period of 38 years. Since the weather station was situated at a lower and warmer location, about 5 miles distant from the pipelines, an allowance of a 5°F. drop in temperature was made. Winter months with a mean temperature below 32°F. occurred in 32 of the 38 years of record. Monthly minimum temperatures averaged 10°F. for 2 months of record and 15 to 20°F. for 16 months of record.

Minimum temperatures ranging from 0 to −5°F. and lasting for several days occurred about 25 times during the 38 years. A characteristic example is given in Table VI. Since a drop in water temperature of 1°F. (from 33.00 to 32.00°F.) can occur in approximately 30 minutes in the steel pipeline at a 25-m.g.d. rate, and since supercooling to 31.90°F., with the attendant danger of forming frazil ice and clogging, could then take place in 3 minutes, it is evident that even a 1-day period would be ample to produce hazardous conditions if heat losses greatly exceeded heat input.

When pipelines are located in a heavily timbered area and where periods of cold weather prevail only for a short period, it is advisable to measure air temperatures along the route of the line rather than to accept values obtained from a weather station in the general vicinity since the heat released by forests during cold snaps can be appreciable. When snow covers pipelines during the Winter months, the insulating effect of this air cell blanket effectively reduces heat losses.

Table VI. Low-Temperature Conditions

Date (1947)	*Max. temp., °F.*	*Min. temp., °F.*
Jan. 28	8	−4
29	0	−7
30	2	−9
31	7	−8
Feb. 1	9	−2
2	20	−2
Av.	8	−5

Well water temperatures are about 50°F. in the northern sections of the United States where wells are the source of supply. This high value should furnish ample heat for the prevention of freezing, even at very low temperatures.

Another point to be emphasized is the advisability of constructing intakes or gatehouses in the deep sections of reservoirs and installing inlets at frequent depth intervals to enable the withdrawal of bottom water at a temperature of 38 to 39°F. during the winter months.

CONCLUSIONS

The logical methods of preventing the freezing of exposed pipelines are to secure the warmest water possible by withdrawing it from the bottom strata of a reservoir, to provide a high flow velocity in the pipe (hence, a short detention period), to blow off water to waste at the end of the line and to check heat losses by means of insulation.

When waters are untreated, blowoff is readily possible. If a treatment plant is employed, however, its capacity may limit such procedure. Insulation is possible and not prohibitive in price, and the use of such materials as wood or "Foamglas" (a highly porous glass) seems economically feasible. If the line can be enclosed in any type of cover so as to produce several inches of dead air space around the pipe wall, freezing would be practically impossible, even under severe conditions.

It is believed that this analysis of freezing conditions in pipelines offers a rational and easily applied method for evaluating the problem, and that it will be of interest to designers and operators of exposed pipes of large diameter. It should also enable considerable economy to be effected by the location aboveground of many smaller-size transmission mains. It is hoped that this paper will promote further research on the problem, and the receipt of any factual data from operating engineers on the performance of pipelines exposed to cold climates will be appreciated by the authors.

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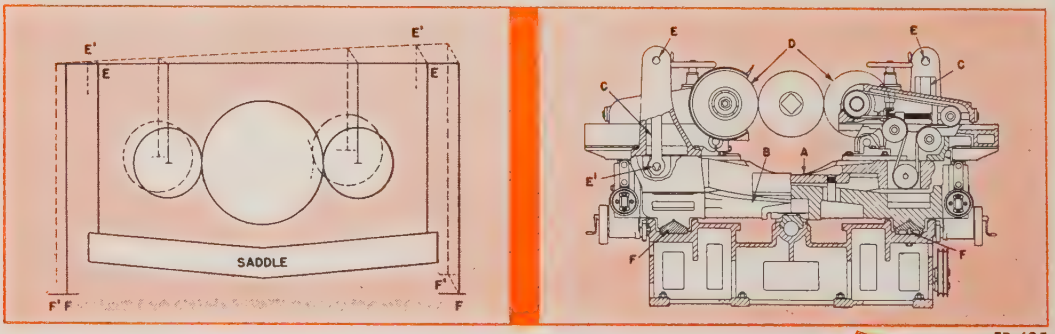

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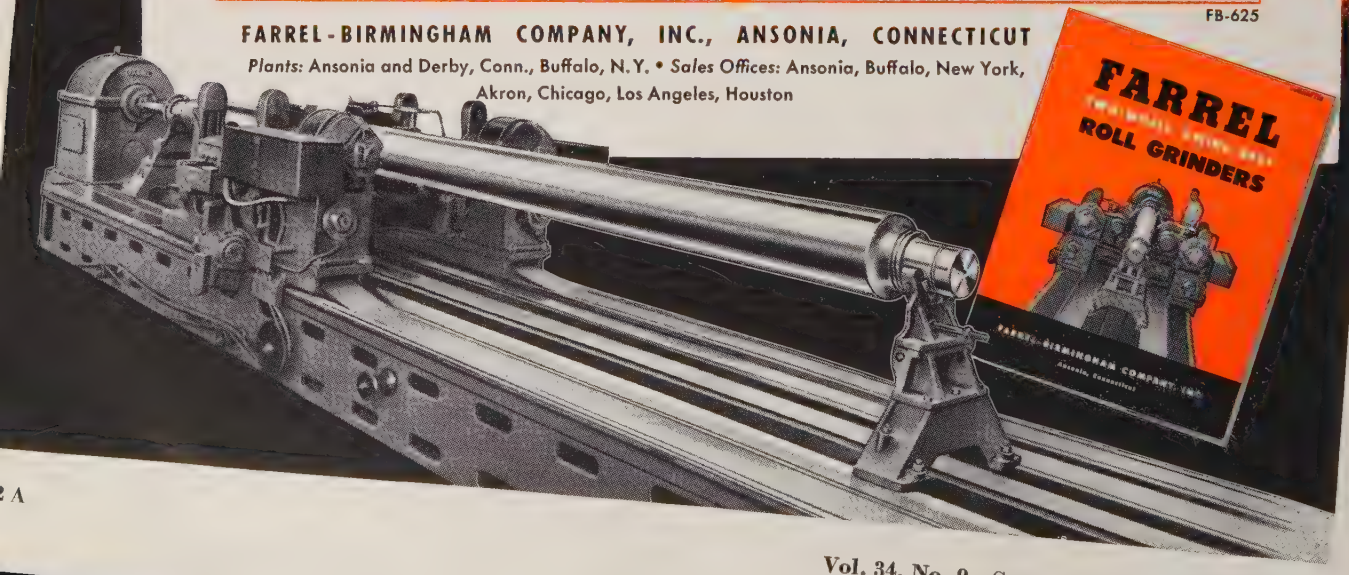

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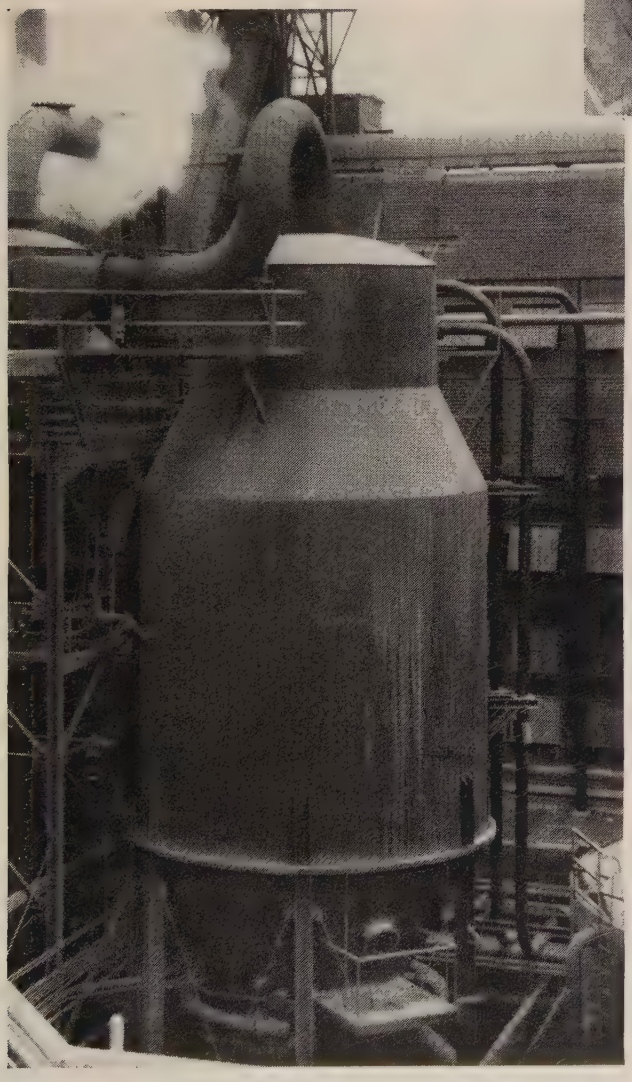

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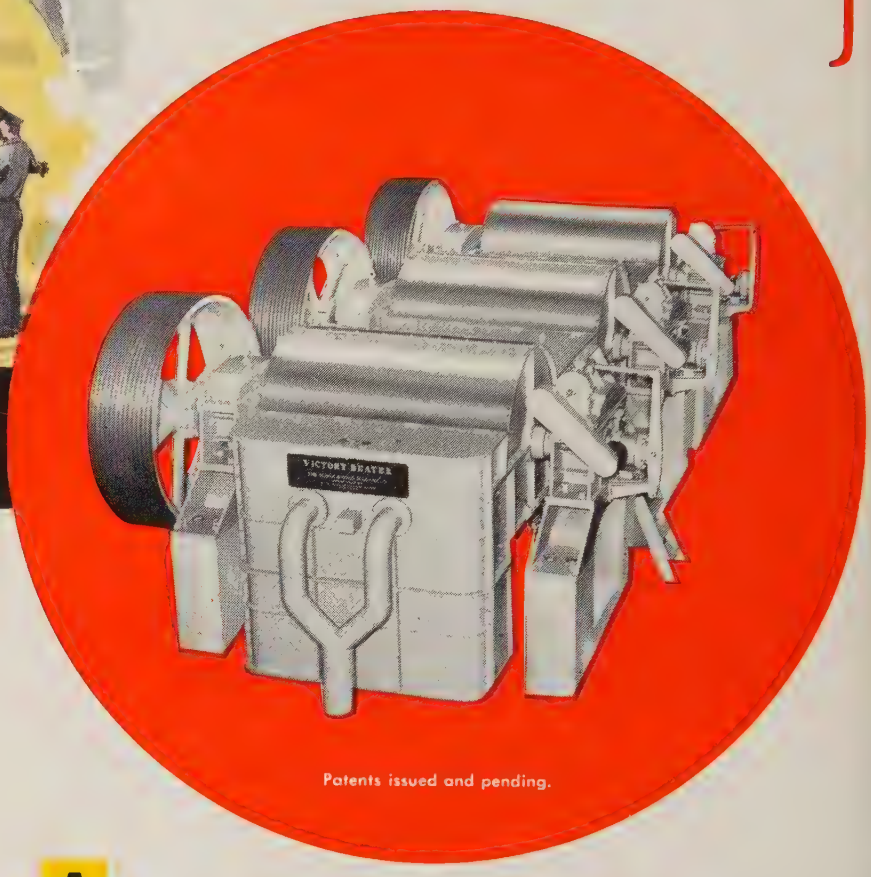

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Redwood as a Potential Source of Pulp

HARRY F. LEWIS

Substantial quantities of redwood are available for conversion to pulp; these include the nonmerchantable lumber from the mill, lumbering wastes in the woods, and second-growth thinnings. Old-growth redwood has a relatively low density and high extractives and lignin content; conventional chemical pulping processes therefore are not attractive economically. Because of its fiber characteristics, such wood makes a desirable raw material for conversion by the Asplund process into roofing or flooring felt. Second-growth redwood is more attractive for conversion by the sulphate process into unbleached and bleached pulps of good quality.

For many years the majestic redwood forests of northern California have gripped the imagination of man. A few of the trees in these groves were already good size specimens at the beginning of the Christian era. Century after century they have added in girth and height, suffering only slight damage from occasional forest fires. During this time the world has seen Mohammed, Charlemagne, the Crusaders, King John, Columbus, Galileo, and Napoleon all come, play their part on the stage of life, and depart.

What is known as the redwood belt of northern California covers an area in Santa Cruz County on the south running up to the north somewhat irregularly through Sonoma, Mendocino, Humboldt, and Del Norte counties in California, and just over the border into Curry County, Oregon. These stands are all near enough to the Pacific Ocean to be hidden by the fogs which drift in almost daily. In this area it is estimated that about 35 billion feet of virgin redwood are now standing.

Redwood operations are presently concentrated in the northern counties of California. The most common type of growth, known as redwood slope, is found on the steep sides of the coast range where the redwood is mixed with red and white fir and tan bark oak. Here it ranges all the way from high altitude and steep slopes down to the more moderate slopes at the lower altitude; finally at the base of the hills the slope is gone and redwood growth of a second type—namely, redwood flats—is found.

Redwoods obtain their greatest height and clear length when growing in the flat land; this is the best timber. In the extreme form, the redwood flat contains only redwood. It should be stressed, however, that the flats make up only a small percentage of the forest. On the slopes the trees rarely exceed 225 feet in height and 10 feet in diameter. On the flats, trees have been found which were 350 feet high and 20 feet in diameter.

The quality of the redwood varies with the location of the tree. The best timber is said to come from the bottom land, although there is considerable variation in trees in the same location. Much information on the types of redwood and yields will be found in the "Study of Redwood" by Richard T. Fisher (Bureau of Forestry, Bull. No. 38. Washington, 1903), and in "California Redwood and Its Uses" (U. S. Department of Commerce, Trade Promotion Series No. 171. Washington, 1937).

During 1950 it is estimated that about 900,000,000 feet of redwood were cut, together with 500,000,000 feet of white woods and Douglas-fir from adjacent forests but milled in the redwood region. In these operations, a large amount of nonmerchantable lumber results. Such wastes fall under the following headings: stumps and roots; woods waste such as broken logs, tree tops, fire-scarred wood, branches, and bark; and mill wastes including small dimension slabs and sawdust from head and trimmer saws, etc. The amount of the various wastes will vary with the operation, depending upon the lay of the land, difficulties in getting the wood to the loading stage, the quality of the wood, the equipment, and the skill of the operators both in the woods and at the mill.

WOODS WASTE

Some studies were made by Emanuel Fritz of the University of California on the losses of sound, merchantable redwood from a 29-acre operation in Humboldt County in 1928 and 1929. The data collected are representative of the area studied but will differ for other conditions. The timber being logged ran about 100,000 feet to the acre. In Table I the various deductions and losses have been calculated on a percentage basis; however, for the purpose of this review the losses have been calculated to the gross Spaulding scale of merchantable content rather than using the Spaulding rule as given by Fritz. For waste utilization purpose, all the wood substance should be calculated as available for use. The data give no information at all about the wood substance in the roots and stumps, nor do they indicate the volume of wood not considered merchantable in the tops, limbs, etc.

Felling breakage is clearly indicated as being responsible for the greatest amount of woods waste. Breakage of redwood on felling is greater than for any other timber species according to Fritz. Reduction in waste resulting from breakage can be decreased by the preparation of a good layout to eliminate high points which serve as fulcrums and by chopping so as to avoid "crossing," the term used to designate the felling of a tree across one already down. In one illustration given by Fritz, the actual breakage in felling was reduced to about 1.2% by careful operation. A great deal of the wood substance spoiled by breakage is satisfactory in some form of a pulping operation.

Hollow butts and rot run into a sizable loss. The sound wood substance from hollow butt would be converted in a pulping operation into some form of pulp

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and so should be counted as available waste. Flash fire burn, rift cracks, and yarding and loading breakage together cover the greater share of the other wood losses. The flash fire losses can be reduced by peeling the bark from the logs at the mill. Since the bark protects the log from fire damage, flash fires cause little or no damage under these conditions. Losses from checking of the peeled log can also be reduced, provided the logs are taken to a log pond after peeling and remain there until they go to the sawmill. Unfortunately, the data do not show the nonmerchantable wood substance left in the woods as tops, limbs, etc. This has been estimated at 10 to 15% of the Spaulding scale of the tree. A great deal of this would be satisfactory for some type of pulping. A rough estimate of this would be 2 to 4 tons per stump or 45 to 70 tons per acre where the logs scale approximately 100,000 feet board measure per acre.

Table I. Losses in Redwood Logging Calculated to the Gross Spaulding Scale
(Number of trees felled—672)

	Amount, ft.	*Percentage of total*
Total (Spaulding scale)	4,554,698	100.0
Hollow butts and rot	346,263	7.6
Rift cracks and shakes	108,657	2.4
Undercut	7,304	0.16
Felling breakage	796,004	17.4
Slash fire damage	235,203	5.2
Error in marking log lengths	5,996	0.13
Bucking breakage	10,144	0.21
Yarding and loading breakage and damage	56,597	1.24[a]
Other losses	7,900	0.17

[a] This figure appears to be much below the usual expected loss in breakage in yarding and loading. This figure will often run up to 10%.

MILL WASTES

Figures were not obtained for the mill wastes from the same logs covered in the woods waste study. However, data are available for a long operation. In one such test for a sawmill cutting 430,000 feet board measure (Humboldt scale) per 9-hour day, the volume of sawmill waste was about 525,000 feet board measure, or more waste than recoverable wood as lumber. If the production of the mill is looked upon as 500,000 board feet of lumber measure per day, mill wastes will total about 91.8 cords of selected heart waste, 162 cords of miscellaneous wastes, 97.5 cords to the burner, and 62.5 cords as sawdust, or a total of 514 cords per day based on the conditions which obtained in 1941. It should be pointed out that the particular mill in which these figures were developed (The Pacific Lumber Co. of Scotia, Calif.) has inaugurated an extensive program of wood waste utilization and, as a result, the wastage of the type called selected heart waste and miscellaneous heart and sapwood waste finds its way into some form of pulping operation. This will develop during the course of the paper. These are not the only wastes around the mill making finished lumber, for there are the wastes coming from the wood-converting operations. At Scotia the sawdust from this operation finds its way into the manufacture of Pres-to-logs; that portion which is not converted in this fashion because of its size is used to produce steam.

The annual amount of potential pulp material (calculated to the dry basis) and normally available from a redwood operation of the size of The Pacific Lumber Co. plant at Scotia operating on a 300-day year would be as follows: woods waste, approximately 136,000 tons; and lumber mill waste, approximately 171,000 tons. Fifteen per cent or so of the latter is sawdust and not too useful in a conventional pulping operation. Only the mill waste is now located where it would be available for use.

Not only is there an annual production of waste material from the current operations, but there are available on the vast areas of the cutover land stumps and tops of trees having a diameter of 3 feet or less which have not been burned in the slash fires. Only a relatively small area of such land has been cleared for agricultural purposes, and an enormous amount of the material can be obtained. A guess is that this runs into billions of board feet, but the subject should not be left without pointing out that these figures are only approximate. They are incorporated for the purpose of showing that wastes exist in such amounts in the redwood logging operations as to warrant their consideration as a source of fibrous raw materials.

SECOND-GROWTH REDWOOD

A considerable quantity of second-growth redwood has now grown up in the cutover areas not under cultivation. Such material comes in part from seedlings and in part from fresh growth starting from the stumps and roots of the virgin wood. Old redwood stumps sprout readily. After a period the area is dominated by the second-growth redwood. It is estimated that there are 5,000,000,000 feet of this second growth, much of which would profit from careful thinning.

Some idea of the rate of growth of second-growth material can be obtained from the study of Fisher [U.S. Dept. Agr., Bur. of Forestry, Bull. 38 (1903)]. He studied an area near Crescent City from which the original timber had been cut 30 years earlier. The stand was 6 acres and had not been burned since the original logging operation. He also investigated two tracts near Eureka and Arcata, the first 35 years and the second 40 to 45 years of age. After 30 years the Crescent City stand showed 30 redwood trees per acre with an average diameter of 16 inches or more (breast high) and 204 trees per acre with a diameter of 2 to 13 inches. The Arcata site had 30 trees per acre with an average diameter of 17 inches and 162 trees between 2 and 13 inches. A tree 14 inches in diameter will average 69 feet high and one 17 inches will average 78 feet. The highest tree in the Crescent City area was 100 feet, with a number running between 86 and 95 feet. The actual yield of merchantable material at Crescent City runs almost 2500 board feet per acre. The growth, of course, is variable and depends on the location and the condition of growth. As an illustration, Fritz (Western Forestry and Conservation Association Conference, San Francisco, Calif., Dec. 6, 1950) tells of a 100-year-old tree in which the growth rate increased from a fraction of 1 to 20% per year for the first 10 years following thinning.

Thus it will be seen that, in part at least, redwood reforests itself provided fires do not interfere and that such growth occurs at a very rapid rate. The second-growth tree shown in Fig. 1 had a height of about 40 feet and a diameter of about 10 inches. It will be noticed that the limbs start slightly above the ground. The trees in Fig. 2 varied in height from 75 to 100 feet.

Fig. 1

The diameter of the largest tree was 24 inches. These trees are 20 to 35 years old. The tree shown in Fig. 1 was 10 years old.

THE PHYSICAL PROPERTIES OF SECOND-GROWTH AND VIRGIN REDWOOD MATERIALS

The two important physical properties of wood which interest the pulpmaker particularly are the density of the wood and the dimensions of the fibers making up the wood. The density is important in that it determines how much wood substance will go into the digester as chips. The dimensions of the fiber relate to the papermaking qualities of the pulp made from the wood. The stiffness of the fibers is associated with the thickness of the fiber wall. Thin-wall fibers are more flexible than the thick-wall fibers.

Both old and second-growth redwood generally rate at the low end of the pulpwood density scale, and there is little difference between old and young wood. In general, sapwood will have a lower density than heartwood; an average density (in pounds of dry wood per cubic foot) is 23 to 24. Yellow birch has a density of 41, longleaf pine 39, black gum 34, Douglas-fir 29, black spruce 28, western hemlock 27, ponderosa pine and white spruce 24, redwood and cottonwood 23, white fir 22, and western red cedar 21.

The average fiber lengths of the commoner pulpwood fibers are all below the average fiber length of redwood. In fact, it is said that redwood fibers are the longest wood fibers available to the papermaker. Starting with redwood as 6.12 mm., the others run about as follows: western hemlock 4.2 mm., Douglas-fir 3.9 mm., jack pine 3.4 mm., black spruce 3.3 mm., black gum 3.2 mm., yellow poplar and yellow birch 1.9 mm., and black gum 1.8 mm. The redwood fibers may have greater diameters than the common papermaking fibers; redwood fibers often have diameters in excess of 60 mm. in contrast to Douglas-fir with 48, longleaf pine and western hemlock with 45, black spruce with 33, and black gum with 32. Redwood fibers have been found to run between 2.9 and 9.5 mm. in length and up to 80 microns in diameter. Second-growth redwood fibers are somewhat shorter; one composite group showed an average length of 4.45 mm. with the range between 1.1 and 6.8 mm. The average width was 57 microns, varying from 30 to 100 microns.

The Components of Old and Second-Growth Redwoods

Not only are we interested in the physical nature of wood but in its composition as well. A large content of so-called "extractives" means less actual wood substance as fiber. A high lignin content (which is removed in chemical pulping) means less fibrous cellulosic material for pulp. Some woods exhibit a lower ratio of holocellulose to lignin than do other woods, and this also points to a low pulp yield. For these reasons, we must concern ourselves with the composition of new pulpwoods.

A vast amount of analytical work has been carried out at The Institute of Paper Chemistry covering the amount and nature of the various components of the different types of available redwood materials. These have covered branches, sapwood, heartwood, stumps,

Fig. 2

and roots in the case of the virgin redwood and both sap- and heartwood in the case of the second growth. The principal components of redwood heartwood include, in addition to the conventional materials such as cellulose, lignin, the hemicelluloses, and uronic acids, extractives of the type of the water-soluble tannins, the alcohol-soluble condensed tannin which is known as phlobaphene, together with smaller amounts of cycloses and reducing sugars which are found in the alcohol-soluble fraction. Table II shows the distribution of the more important components of old-growth redwood.

Similarly, from the last section it will be seen that the pulpwoods described all have more desirable compositions than redwood in terms of potential pulp yields in that they have either a lower content of extractives and/or lower lignin and higher holocellulose content. This is particularly true for the old-growth heartwood. Tree tops, old sapwood, and second growth all show a lower extractives content and a higher cellulose and lower lignin content than the old heartwood. This would favor these types for chemical pulping. Not much difference in density is observed among the various samples under test. One way to increase the yield of pulp would be to remove the extractives and pulp the residue. This has been done with the expected results.

Table II. Summary of the Chemical Constants of Redwood Samples Calculated to Moisture-Free Wood

Chemical components	*Sapwood*	*Heartwood*	*Limbs*	*Green stump*	*Old stump*	*Roots*
Cross & Bevan cellulose, %	53.5	45.2	41.0	42.5	44.0	37.5
Pentosans, %	12.2	10.2	14.4	7.9	8.9	5.7
Reducing sugars, %						
Water soluble	0.4	0.7	0.5	0.5	0.5	0.4
Alcohol soluble	0.02	0.3	0.5	1.0	0.7	1.1
Cycloses (pinite and sequoyite), %	0	1.2	0	2.1	1.9	0.02
Polyuronides, %	3.9	3.3	4.0	2.1	3.2	2.2
Lignin, %	32.2	30.8	32.6	29.9	31.4	25.5
Tannins, %	0.2	4.1	2.4	4.1	3.8	7.8
Phlobaphenes, %	0.7	6.2	4.0	7.6	3.2	22.1
Oxidized phlobaphenes and humic acid, %	1.4	1.7	1.3	1.6	2.0	2.4
Soluble salts, %	1.2	0.8	1.3	1.7	0.7	0.6

In Table III the principal components of second-growth wood and old-growth wood, both on an unextracted basis and on an extractive-free basis, are summarized. The old-growth wood is seen to contain about 5% less alpha-cellulose and 2.5% more lignin than does the second-growth wood. In addition, the tannin content of the second-growth wood is very much less than that of the old-growth wood; more than half of the second-growth wood is sapwood which is free of tannin and the tannin content of the young heartwood is relatively low. These differences in chemical composition play an important part in the differences in actual pulping behavior, as might be expected.

A comparison has been made in Table IV of the important components of redwood with those of black spruce, Douglas-fir, western red cedar, western hemlock, and loblolly pine.

On the basis of composition alone, we might expect the yield of pulps of the same lignin content (permanganate number), when compared with the yield of pulp of the same permanganate number from second-growth redwood, to be in the holocellulose ratio described above. Similar ratios have not been established for old-growth wood for the analytical work on old redwood predated the development of a reproducible analytical method for holocellulose. In one series of pulps this has been found in general to be the case.

Table III. Comparison of the Quantities of Principal Components in Old and Second-Growth Redwood

	Oven-dry basis		*Oven-dry extractive-free basis*	
	Old wood	*Second growth*	*Old wood*	*Second growth*
Alcohol soluble,[a] %	10.75	7.2	...	...
Hot water soluble,[a] %	1.4	1.1	...	...
Ash, %	0.13	0.15	...	...
Lignin, %	31.2	30.2	35.5	33.0
Cross & Bevan cellulose, %	45.2	50.6	51.5	56.2
Alpha-cellulose, %	37.0	43.3	42.1	47.3
Pentosans, %	8.6	12.3	9.8	13.4
Uronic anhydride, %	3.3	3.3	...	...

[a] By successive extractions.

The types of redwood included in the experimental pulping program were the following—the composite from an old tree, sapwood from virgin stock, conveyor waste (mainly heartwood virgin stock), water-extracted conveyor waste, and second growth about 30 years old.

PULPING AND BLEACHING OF REDWOOD

As will be seen from an earlier section, the density of redwood is considerably lower than the densities of such common pulpwoods as western hemlock, Douglas-fir, loblolly, longleaf, and jack pine, black and Sitka spruce, and many of the hardwoods. Western red cedar, lodge pole and ponderosa pines, white and Engelmann spruce, and cottonwood have about the same density as redwood. This means that a greater weight of the majority of the commonly used pulpwoods may be charged into the digester, which means increased production, other things being equal.

Sulphate Process

In general, it can be said that old-growth redwood is best reduced to chemical pulp by the sulphate process with yields of 37% pulp having a permanganate number of 30; the pulp produced may be bleached to a brightness of 80 and an alpha-cellulose content of 82% with a chlorine consumption of 10%. The sapwood of the same age cooked in the same way gives pulp yields of 41.5 to 42%. Extracted old-growth redwood falls in between with a yield of 39 to 40% pulp. Second-growth wood, approximately half heart and half sap, gives the best yield (43.5%) when pulped to the same permanganate number under essentially the same cooking conditions. These yields compare with those of 52.7% for

Douglas-fir, 49.5% for western hemlock, 53.4% for spruce, 51.0% for loblolly pine, and 50.0% for western red cedar at the same permanganate numbers.

Generalizations with regard to pulp quality are dangerous because by careful control of cooking and bleaching, it is possible to obtain pulps having improved properties, although the conditions which result in this improvement may be often outside the scope of economic mill operation. As an illustration, the above results obtained on cooking heartwood conveyor waste may be cited. By using 30% caustic as NaOH with 33.3% sulphidity at a liquor ratio of 6.5:1 (the maximum temperature of 160°C. was reached in 3 hours and the digester was held at that temperature for 3.5 hours), a pulp is obtained in 37.7% yield with a permanganate number of 30.4, which shows a burst of 171 at a freeness of 570 and a beating time of 65 minutes, and a tear of 4.12 after 5 minutes of beating and 2.28 after 65 minutes. This pulp has been bleached by a multistage process (chlorine, alkaline extraction, and hypochlorite) to a brightness of 79.9 with a bleach consumption of 10.3% chlorine. The bleached pulp has a burst of 139 at a freeness of 610 and a tear of 1.68. The burst is 155 at 360 freeness and the tear is 1.64. A commercial bleached Swedish kraft tested at the same time had a bursting strength of 138 at a freeness of 655 and a tear of 1.44.

The pulp from second-growth wood has a burst of 200 and a tear of 1.43 after the same beating time. The pulp from old-growth sapwood has much the same characteristics as the pulp made from old-growth heartwood. These strength results may be summarized by saying that the second-growth wood yields a sulphate pulp very similar to the sulphate pulp from spruce in quality, whereas the sulphate pulp from the old wood is inferior to the sulphate pulp from Douglas-fir in tear, but has somewhat better bursting strength.

Incidentally, the redwood sulphate pulps all have an unusually high Schopper-Riegler fold—that from the sapwood had 5000 double folds.

Sulphite Pulping

Redwood can be reduced by the sulphite process. Old redwood has been converted to an unbleached pulp in a yield of 35.3% by cooking for 15.5 hours with a total acid of 7.15% SO_2 (free sulphur dioxide, 5.90 and combined sulphur dioxide 1.25%). The maximum temperature reached was 140°C.; the liquor to wood ratio was 5.0:1. The resulting pulp had a permanganate number of 15.0, a copper number of 3.91, and a viscosity of 8.9. The yield was raised to 41.4% by cooking water-extracted wood with about the same conditions. This pulp had a permanganate number of 9.5, copper number of 3.73, and viscosity of 15.0. When bleached with 1.9% chlorine and 1.1% hypochlorite (expressed as percentage of available chlorine), a pulp of 79.2 brightness and a viscosity of 15.2 was obtained. Sapwood was reduced much more easily by the sulphite process; in 10 hours (instead of the 15 used in the heartwood cooks), a pulp was obtained in 43.3% yield having a permanganate number of 14.8, a copper number of 2.67, and a viscosity of 52.5. Using 3.0% chlorine and 1.1% hypochlorite (expressed as percentage of available chlorine) a pulp brightness of 83.9, viscosity 33.5, and alpha-cellulose content of 86.3 resulted.

The sulphite pulps had bursting strengths of about 100 points; the initial tear was in the general range for corresponding pulps made from Douglas-fir. The redwood sulphite pulps exhibit the same high folds that were shown by the sulphate pulps.

Nitric Acid Pulping

During the earlier years of the redwood pulping studies, a considerable interest was expressed in the nitric acid process. A number of experimental nitric acid pulps were made to determine whether these might be of interest in the manufacture of cellulose derivatives. In general, the pulping conditions employed included two stages of boiling at atmospheric pressure with relatively dilute nitric acid; following each acid treatment, the product was extracted with sodium hydroxide solution.

Although the study might have been further expanded, the probable results did not appear to be sufficiently promising to warrant the study. For the sake of the record, the following conditions and results were achieved. *First stage*, acid concentration 4.0%, liquor to wood ratio 8.3, time to boiling 1.5 hours, time at boiling 1 hour; *second stage*, acid concentration 2.0%, liquor to wood ratio 6.0, time to boiling 0.5 hour, time at boiling 2 hours. Alkaline extractions were made with caustic soda using 1% concentration at a liquor to wood ratio of 6.0. Time to boiling 0.25 hour, time at boiling 0.5 hour. The pulp yield was 43.3%; the pulp had a permanganate number of 9.8 and a copper number of 2.39. This pulp was bleached in three stages with 40% of the chlorine requirement in the first stage at 3% consistency. After the first stage the pulp was washed with water and with caustic (1% on the pulp weight) at 4% consistency and then rewashed. When bleached with hypochlorite (1.75% calculated as available chlorine) at 6% consistency and 37°C., the brightness was 80. The bleached pulp had an alpha-cellulose content of 84.3% and a viscosity of 18.8.

Other Pulping Methods

The Asplund process has been found to afford a very satisfactory first step for converting redwood into a

Table IV. A Comparison of the Composition of Redwood with That of Five Important Pulpwoods

	Redwood		*Douglas-fir*	*Western hemlock*	*Loblolly pine*	*Black spruce*	*Western red cedar*
	2nd growth	*Old heart*					
Total extractives, %	8.3	12.2	5.9	5.3	4.4	4.9	10.2
Holocellulose, %	57.9	56.6[a]	67.1	63.5	67.2	65.6	60.7
Alpha-cellulose, %	43.3	37.0	53.8	48.8	56.2	49.0	47.5
Pentosans, %	12.3	8.6	7.3	9.2	11.7	12.3	9.3
Lignin, %	30.2	31.2	26.7	28.8	28.3	26.7	29.3
Ratio: holocellulose/lignin	1.9	1.8[a]	2.5	2.2	2.4	2.5	2.1
Ratio: holocellulose in wood species/holocellulose in second growth redwood	...	...	1 16	1.11	1.16	1.14	1.05

[a] Calculated.

furnish for saturating papers for roofing and flooring. The wood may be converted directly or following a preliminary hot alkaline treatment. The product is then refined, as in a disk refiner. Redwood fiber thus produced yields a sheet having great saturating capacity. It is blended with small amounts of rag or waste paper stock to yield a good product. Large quantities of nonmerchantable redwood chips (of the type termed conveyor waste) are currently being sold to the board and felt mills of the West Coast for this application. This represents the most immediate outlet for redwood mill waste in the paper industry.

The Masonite Corp. has recently opened a large plant at Ukiah, Calif., for the production of several hundred thousand feet per day of redwood Masonite board.

Laboratory tests have also been made on the use of redwood in 9-point board. The results point to some form of a neutral sulphite semichemical cook in a digester, followed by a refining process suited to the redwood fibers. The normal Asplund treatment gives a pulp which exhibits poor stiffness and fiber bonding and is of little direct interest as the major constituent in 9-point.

A modification of the conventional Masonite process is used by The Pacific Lumber Co. for the production of a pulp which may be of interest in the production of resin-impregnated laminates. Its particular interest lies in the fact that hard laminates with low water absorption may be produced with a mixture of the redwood pulp and kraft at resin contents somewhat below those required to achieve the same result with 100% kraft.

CONCLUSION

Because of low density and high extractive and high lignin-low holocellulose contents, old-growth redwood wastes do not look attractive as potential materials for chemical pulping under the present conditions, although this may change as pulpwood requirements increase. They have a definite place and are currently being used in sizable amounts in the manufacture of saturating felts and boards by the Asplund and Masonite processes.

Second-growth redwood thinnings give higher yields of good quality unbleached or bleached sulphate pulps under favorable pulping and bleaching conditions. Although such thinnings would not be available in an amount of sufficient volume to support a large number of pulp mills, they would appear to be of current interest for a smaller operation.

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The pulping experiments described have been carried out over the years under the direct supervision of Charles Koon, Don Niemeyer, and Loren Forman; the analytical data on the woods were obtained by the Analytical Laboratory of The Institute of Paper Chemistry under the supervision of B. L. Browning and in part by E. L. Kurth; and the information on fiber dimensions, etc., was supplied by John Graff and Irving H. Isenberg.

The author wishes to express his appreciation to The Pacific Lumber Co. not only for their support which has made this investigation possible but for their information on their various operations. Thanks are due likewise to Emanuel Fritz of the University of California at Berkeley for information on redwood woods operations and for much general information on redwood.

Models for the Dynamic Properties of Paper

R. E. HURLEY

It is observed that the attributes of the fibers are of importance in determining the significant properties of acoustical paper. This fact has led to the devising of models which closely duplicate the properties of acoustical paper. These mechanical analogs vary depending on the degree of hydration of the paper which they represent and on the amount of pressure used in the manufacture of the paper. It seems probable that the models may be of value in inferring fiber properties.

During an investigation of the properties of laboratory test sheets in connection with the development of paper for speaker cones, phenomena were noted that were not explainable on the basis of the usual working hypothesis that paper is a structureless entity. These phenomena, on the contrary, duplicate those obtained with mechanical models patterned to represent a fibrous material. The devising of these analogs, which was stimulated by an article by Van den Akker (*1*), may lead to a method of statistically inferring fiber properties from a knowledge of the macroscopic qualities of the paper.

Testing acoustical paper differs from tests on conventional paper. In the former case, a knowledge of the density and modulus of elasticity suffices for complete prediction of the instantaneous dynamic behavior of a sample of given mass. The modulus of elasticity must be measured for incremental time intervals and correspondingly small displacements. The customary measurement of creep and fiber-to-fiber bond strength is not necessary for acoustical paper. Testing to destruction or to permanent deformation is also not necessary for such treatment is not experienced during normal service. It is not surprising, therefore, that models might be developed to simulate acoustical paper even though none has yet been developed to simulate other types of paper tested by the usual methods.

Early in the investigation of speaker paper, it became apparent that the development of any mechanical analog would have to take into consideration two factors. One is that the modulus of elasticity of unpressed, slack-dried sheets varies uniquely with the density of the sheets. The second is that the properties of pressed and unpressed, slack-dried handsheets are dissimilar.

EFFECT OF VARYING HYDRATION

The modulus of elasticity of unpressed, slack-dried test sheets varies with density in the manner indicated in Fig. 1. This curve is obtained by measurement of the two properties for sheets made from pulp of varying hydration. As a first step toward finding a model which has a similar relationship between modulus of

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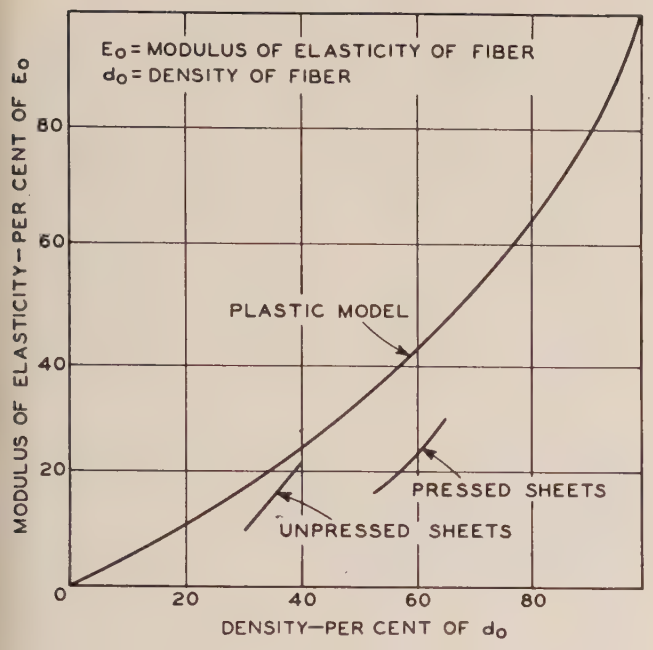

Fig. 1

elasticity and density, perforated sheets of plastic similar to those shown in Fig. 2 were fabricated. Figure 1 also includes a curve of the properties of a series of the plastic-model sheets. Obviously, this curve differs from the curve for the unpressed sheets both in slope and in the fact that it passes through the origin, whereas the other curve does not. These disparities are due to the fact that paper fibers, unlike the theoretical "fibers" of the sheet plastic, are curved and have finite length. Furthermore, the plastic model does not allow for the passage of one fiber over another.

A more suitable analog for the unpressed sheets was then created in the form shown in Fig. 3a. The analog consists of two identical columnar sections analogous to fibers, at right angles to each other, and contacting each other at a point analogous to the fiber-to-fiber bond. The ratio of length to diameter of these sections equals the ratio of the average distance between fiber-to-fiber bonds in the actual paper to the average diameter of the actual fibers. The sections are parallel to the x and y axes. For calculation of modulus of elasticity in the y direction, it is assumed that there is elongation only in the y direction. The resistance to this elongation resides in the y fiber section. The modulus of elasticity of the solid material of the columnar section is called E_o. The increase of force with increase of length of the model in the y direction is described as follows:

$$\frac{df}{dy} = E_o \frac{\text{area of section}}{\text{length of section}}$$

where df/dy is the change in force with change in length.

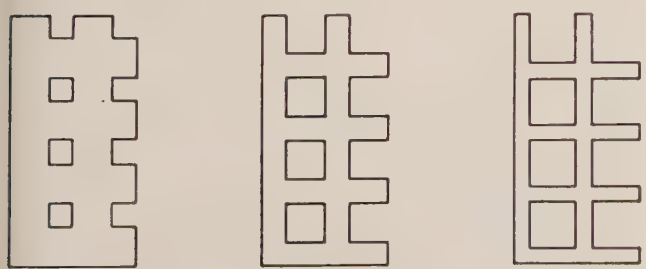

Fig. 2

The apparent modulus of elasticity of the over-all model is designated as E and is evaluated as follows:

$$E = \frac{df}{dy} \cdot \frac{\text{length of model in } y \text{ direction}}{\text{area of model in plane normal to } y}$$

Substituting for df/dy,

$$E = E_o \frac{\text{(area of section)}}{\text{(length of section)}} \cdot \frac{\text{(length of model in } y \text{ direction)}}{\text{(area of model normal to } y\text{)}}$$

$$= E_o \cdot \frac{\pi a^2}{4L} \cdot \frac{L}{2aL}$$

$$= E_o \frac{\pi a}{8L}$$

where a and L are the dimensions shown in Fig. 3. Density (d) of the model becomes:

$$d = d_o \frac{\text{volume of sections}}{\text{volume of model}}$$

$$= d_o \frac{2\pi a^2 L}{4 \times 2aL^2}$$

$$= d_o \frac{\pi a}{4L}$$

where d_o is the density of the fiber material itself.

Figure 3a represents a sample of paper with fiber-to-fiber bonds of sufficient tenacity but of negligible area. This corresponds to a sample formed without pressure from a pulp of minimum hydration. Figure 3b represents a sample of unpressed paper made from pulp of higher hydration. The fibers have sunk into one another "log-cabinwise" until their combined thickness at the bond is $1.5a$ instead of $2a$. It may now be assumed that the cross-sectional area of the y fiber in the region of the bond is twice what it was before because it is supported by the x fiber. The modulus of elasticity of the model is now defined by the following equation:

$$\frac{1}{E} = \frac{\text{area of model}}{\text{length of model}} \left[\left(\frac{dy}{df}\right)_{\text{fiber}} + \left(\frac{dy}{df}\right)_{\text{bond}} \right]$$

$$= \frac{1.5aL}{L} \left[\frac{1}{E_o} \cdot \frac{L - a}{\pi a^2/4} + \frac{1}{E_o} \cdot \frac{a}{2\pi a^2/4} \right]$$

$$= \frac{1}{E_o} \frac{6L - 3a}{\pi a}$$

and

$$E = E_o \frac{\pi a}{6L - 3a}$$

The apparent density becomes:

$$d = d_o \frac{\pi a}{3L}$$

Figure 4 shows a plot of the apparent properties of both models with varying ratios of a to L from values shown in Table I. Curve P shows the changes in apparent properties of lightly adhered paper up to the limiting density of $\pi/4\ d_o$ which would be obtained with ideal packing efficiency of fibers with round or elliptical cross section. Curve Q shows the properties of strongly adhered fibers. If it is considered that the volume of material displaced from the bonds is capable of filling the voids of the model, the limiting density of this model becomes d_o with ideal packing efficiency.

The lower limit of density is a function of the dimensions of the fibers of the actual paper. If it is assumed that the slightly curved fiber makes contact in at least three places when it settles into place during the manufacturing process, and is in turn contacted in three

Table I. Data for Graphs of Modulus of Elasticity versus Density for Various Models of Paper

Curve P		*Curve Q*		*Curve R*		*Curve S*	
$E = E_o \frac{\pi a}{8L}$		$E = E_o \frac{\pi a}{6L - 3a}$		$E = E_o \frac{\pi a}{8L} \frac{L^3}{(a^2 + L^2)^{1.5}}$		$E = E_o \frac{\pi a}{6L - 3a} \frac{L^3}{[(a^2/4) + L^2]^{1.5}}$	
$d = d_o \frac{\pi a}{4L}$		$d = d_o \frac{\pi a}{3L}$		$d = d_o \frac{\pi a \sqrt{a^2 + L^2}}{4L^2}$		$d = d_o \frac{\pi a \sqrt{a^2/4 + L^2}}{3L^2}$	
a/L	E/E_o	d/d_o	E/E_o	d/d_o	E/E_o	d/d_o	E/E_o	d/d_o
0.1	0.039	0.079	0.055	0.105	0.038	0.079	0.055	0.105
0.2	0.079	0.157	0.116	0.209	0.074	0.160	0.115	0.210
0.3	0.118	0.235	0.185	0.313	0.104	0.245	0.180	0.316
0.4	0.157	0.314	0.262	0.419	0.126	0.338	0.247	0.427
0.5	0.196	0.392	0.349	0.523	0.140	0.438	0.319	0.539
0.6	0.236	0.471	0.449	0.628				

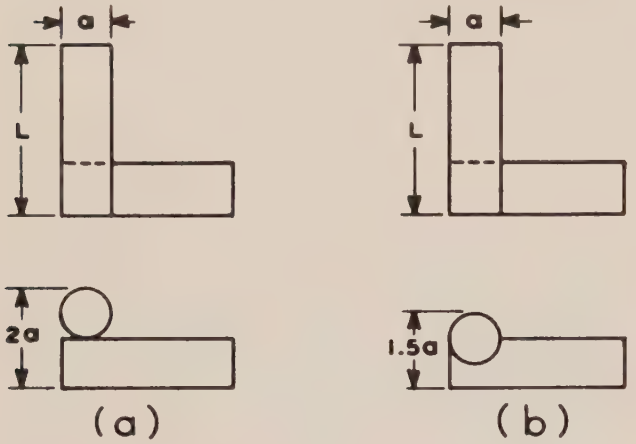

Fig. 3

places by fibers above it, the ratio of a to L of the model would be the ratio of fiber diameter to one sixth of the fiber length.

The lower limit is purely hypothetical since no sample can be formed with so light a pressure as to make the minimum number of contacts. In the experimental work referred to, samples of unbleached sulphite pulp were subjected to the vacuum of a small aspirator and then dried on a photographic print drier. The properties of the lowest density sample are designated as $E = 0.10E_o$ and $d = 0.30d_o$ in terms of arbitrarily chosen values of E_o and d_o. In anticipation of a correction for fiber curvature the first calculated point is assigned the values $E = 0.15E_o$ and $d = 0.30d_o$.

If it is assumed that the lowest density obtainable is $0.3d_o$ and that such a sample has bonds of minimum area, then the properties of the sample must be described by the point p on curve P, Fig. 4. This point corresponds to a ratio of a to L of 0.38.

If it is now assumed that with further hydration the fibers coalesce without changing their shapes or positions until the apparent density of the model becomes $0.4d_o$, the properties of the sample for this density are described by the point q on curve Q, Fig. 4 ($E = 0.245E_o$; $d = 0.4d_o$). In this transformation the ratio of a to L is assumed constant, because the fibers are not rearranged and it is assumed merely that one fiber sinks into another.

The line pq does not satisfy the paper data which form a steeper curve. To adjust the line pq so that it represents the data more closely, it must be assumed that the average fiber is curved, so that its radius of curvature is R and the moment of inertia of its cross section about the neutral axis is $K^2 \pi a^2/4$, where K is the radius of gyration of the cross section of the fiber about its neutral axis. The apparent modulus of elasticity of the model is then reduced by a factor that depends on the shape of that length of fiber that is unsupported by a bond. For the sample of zero bond area the correction factor is approximately:

$$\frac{1}{1 + (L^4/16K^2R^2)} \qquad \text{(see Appendix A)}$$

Since the observed value of E is two thirds the calculated value, a value of $^2/_3$ should be assigned to the correction factor. The expression $L^4/16K^2R^2$ is then equal to 0.5. Since $L = 2.63a$, the constant K^2R^2 must be equal to $6a^4$. Substituting $2.63a$ for L the factors which determine the effect of fiber curl may be lumped in the expression K^2R^2/a^4, which in this case equals 6.0.

If the same correction is applied to the point q, it will affect only that portion of the fiber that is unsupported by a fiber-to-fiber bond. The correction factor becomes:

$$\frac{1}{1 + [(L - a)^4/16K^2R^2]}$$

The value of E' for the corrected point q′ is found by the following formula:

$$\frac{1}{E'} = \frac{1}{E_{\text{fiber}} \left[\frac{1}{1 + [(L - a)^4/16K^2R^2]}\right]} + \frac{1}{E_{\text{bond}}}$$

When E′ is calculated on this basis with the same value

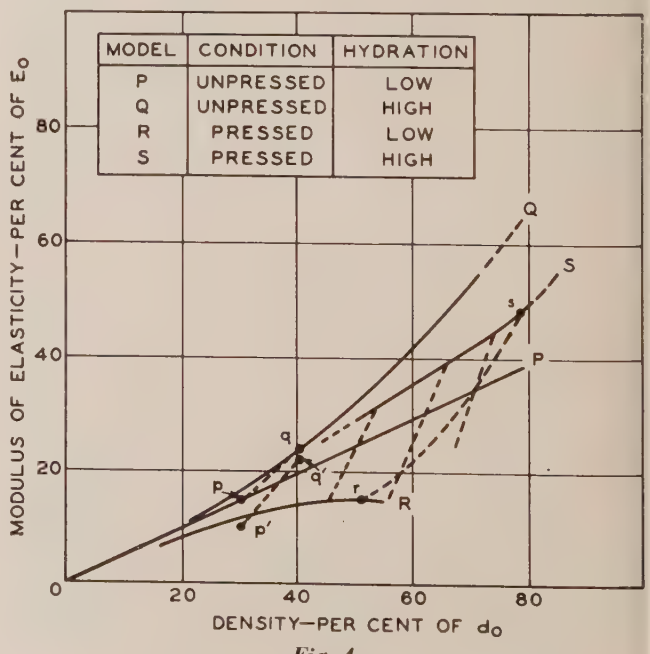

Fig. 4

of K^2R^2 as used previously, E' becomes $0.232E_o$ as compared to the uncorrected value of $0.245E_o$. The line p′q′ is found to satisfy the experimental data.

The correction for fiber endings is neglected, as it appears to be very small compared to the correction for fiber curvature. Even in the case of the theoretical low limit of density where the fibers are bonded at six points this correction would be only one sixth of the total apparent modulus of elasticity.

EFFECT OF PRESSURE

The dissimilarity between the properties of pressed and unpressed paper is illustrated in Fig. 1. This dissimilarity indicates that certain basic changes take place in the structure of the sheet during pressing. These changes appear to be mainly: (1) the introduction of a component of fiber direction at 90° to the plane of the paper, (2) a preferential orientation of the fiber to bring the greater width of its cross section parallel to the plane of the paper, and (3) a broadening of the fiber at the bond, which broadening is dependent on the amount of pressure applied.

The pressed sheets referred to were pressed with a couching roller which produces pressure only at a line of contact and also produces a kneading action which might be important in orienting the cross section of the fiber. In cases where light pressure was applied with a press instead of a roller it was possible to obtain samples with properties falling between the curves for pressed and unpressed paper. Properties of these lightly pressed sheets, however, followed no definite pattern. It appears that a certain critical pressure is required to accomplish the basic changes in the structure and produce the stable structure of pressed paper. Pressure less than the critical seems to bring about a partial conversion to the new structure and this partial conversion has properties that are not at present predictable.

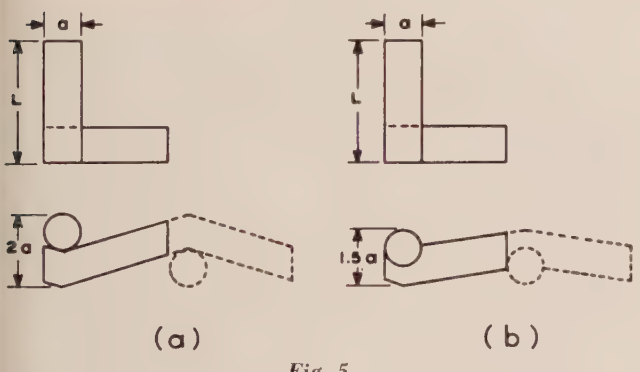

Fig. 5

The models for pressed paper must take into account the fact that the fibers do not maintain their original shape, but bend in order to pack more closely. Figure 5a shows a model for pressed sheets in which there is no tendency for the fibers to coalesce. In this case the apparent modulus of elasticity and density are as follows:

$$E = E_o \frac{\pi a}{8L} \frac{L^3}{(a^2 + L^2)^{1.5}} \qquad \text{(see Appendix B)}$$

$$d = d_o \frac{\pi a \sqrt{a^2 + L^2}}{4L^2}$$

Data from these equations are plotted to form curve R Fig. 4. It appears from inspection of the model that curve R must have a limit at about $d = 0.55d_o$.

Figure 5b shows a model similar to that shown in Fig. 5a except that coalescence is the same as was assumed for the plotting of curve Q. The apparent E and d are expressed as follows in this case:

$$E = E_o \frac{\pi a}{6L - 3a} \frac{L^3}{(a^2/4 + L^2)^{1.5}}$$

$$d = d_o \frac{\pi a \sqrt{a^2/4 + L^2}}{3L^2}$$

These data are plotted to form curve S, Fig. 4. This curve has no density limit due to the permissible deformation of the fiber at the fiber-to-fiber bond.

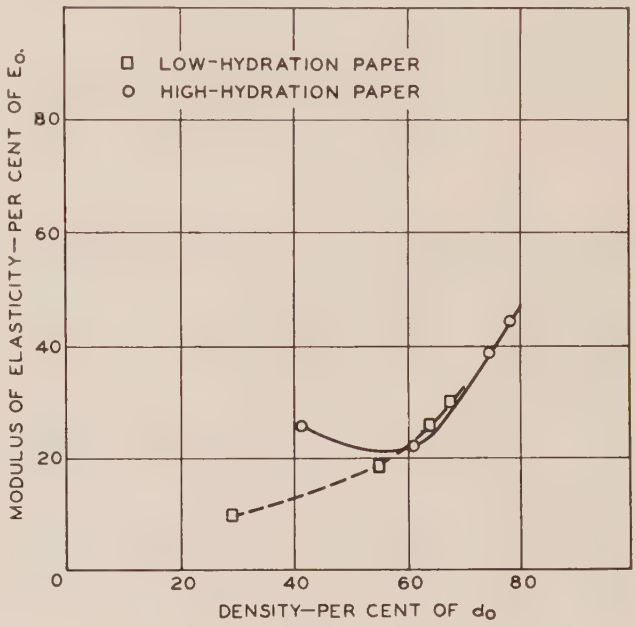

Fig. 6

For unpressed sheets it was assumed that with increasing density the fibers suffer no rearrangement and no change in general shape and that the ratio of a to L remains very nearly constant. But when the sample is pressed, the fibers not only become bent but seem to rotate or compress so that their broader diameter becomes parallel to the plane of the paper. This effect increases the effective value of a and changes the ratio of a to L. If the average cross section remains elliptical, the equations undergo no change. The value of L may also become smaller if, during condensation, more bonds are formed. So, in describing the condensation of the sample by pressure, one can assume that a change occurs in the ratio of a to L.

The original curvature of the fiber is of little importance now because the length of unbonded fiber is very short and because the fiber has changed shape.

If the sample represented by the point p′ is compressed, it will move to some point on the curve R, Fig. 4. Experimentally, this point is found to correspond to a density of about $0.5d_o$ at the point r.

If we now consider a series of samples made from pulps of steadily higher hydration, the properties progress from the point r to a point on curve S. This process, however, is not accomplished without a change in the ratio a to L. Experimental data show that such a

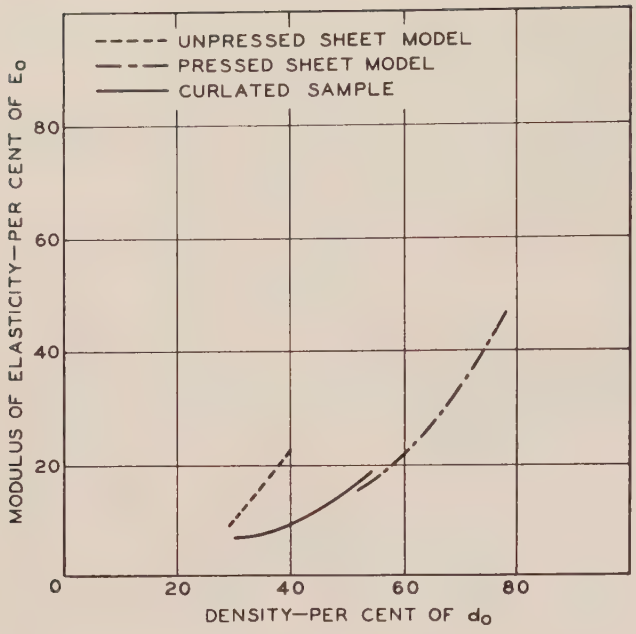

Fig. 7

series of samples follows the curved line rs, Fig. 4, indicating an increase in the ratio of a to L. The dotted lines laid between curves R and S indicate lines of equal ratio of a to L.

One surprising detail is that increases in pressure above the critical pressure required to bring the sample to the line rs cause the properties to progress in the same manner as though the pulp had been processed to a higher degree of hydration. Figure 6 shows two sets of samples made from two pulps; one of a low degree of hydration and the other of a high degree of hydration. The similarity of properties of the two series after they have reached the curve corresponding to rs of Fig. 4 is very evident.

SUBSTITUTION OF MEASURED VALUES

The data thus far have been given in terms of E_o and d_o. When measured values are applied to the curves in Fig. 4, it appears that E_o must be 11×10^{10} dynes per square centimeter. This value can be interpreted as the modulus of elasticity of the unbleached sulphite fiber used in the experiments.

The density of the fiber appears to be very nearly 1.0 grams per cubic centimeter. The apparent discrepancy between this value and the usually accepted values for density of the fiber material may possibly be explained by the effect of shrinkage; that is, the fiber may respond as a solid filament during sheet formation but may develop voids or a surface structure on drying. The value of d_o is therefore the apparent density of the fibers.

EXPERIMENTS WITH CURLATED PULP

Several tests were made with "curlated" pulp. The unbleached sulphite pulp used in the other experiments was curlated prior to sheet formation. Figure 7 shows the relation between the two pertinent physical properties of these sheets for comparison with the lines p′q′ and rs taken from Fig. 4. The hydration of all the curlated samples was the same, but the pressure of sheet formation was varied. The data seem to form a continuation of liners extending into the low-density region.

EXPERIMENTAL ERRORS

This development would not be complete without a discussion of probable error. The method of measuring modulus of elasticity was the vibrating-reed method described by Oliver (*2*). The data offered are subject to error from one main source; namely, the measurement of paper thickness. The only method available for measuring thickness was the Schopper gage. Due to compression applied to the paper in this measurement (approximately 1 kg. per sq. cm. pressure), it may be expected that the values of modulus of elasticity of soft, low-density papers are too high. The values of resonant frequency of the vibrating reed, the length of the reed and the weight per unit area of the reed can be measured with sufficient accuracy, but the thickness is measured with difficulty. E is obtained as follows:

$$E = \left[\frac{6.19 l^2 \nu}{t}\right]^2 \frac{w}{t}$$

where l is the length of vibrating reed, ν is the fundamental resonance, t the paper thickness, and w the weight per unit area.

If the accurately measured quantities are placed on the right side of the equation, then

$$Et^3 = [6.19 l^2 \nu]^2 w$$

or,

$$\frac{E}{d^3} = [6.19 l^2 \nu]^2 \frac{1}{w^2}$$

Therefore, E/d^3 may be measured with great accuracy. The probable error in E would be found distributed along a cubic parabola $E = Kd^3$.

CONCLUSION

The author would like to express the hope that the

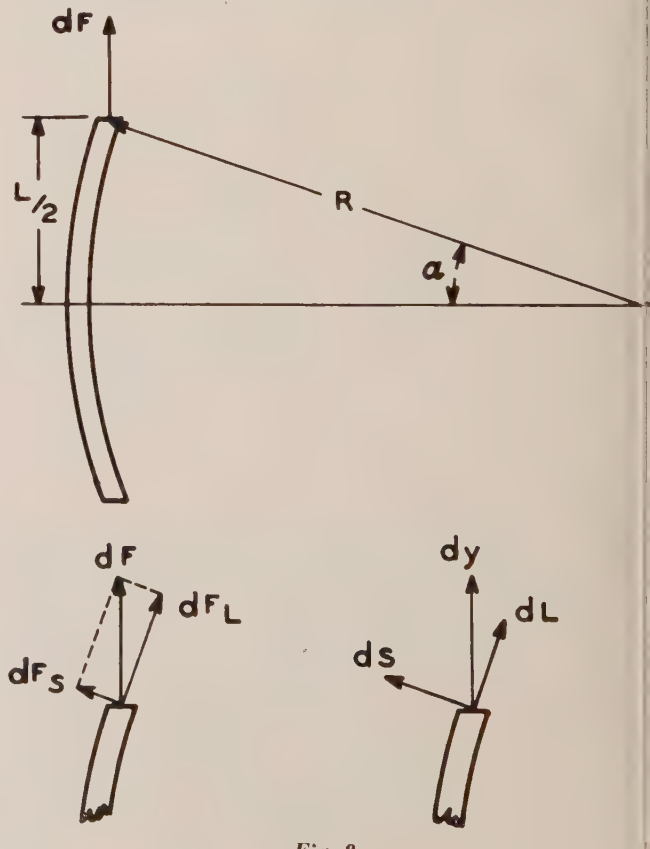

Fig. 8

method of development presented will lead to a statistical determination of the properties of the papermaking fibers and lead eventually to the establishment of measurable quantities to replace the qualitative terms which are still used to describe some of the fiber properties.

APPENDIX A

It is assumed that a fiber of approximate length L and diameter a with a center line having a radius of curvature R is subjected to a stress dF. The fiber is considered as two rods of length $L/2$ fixed at the midpoint of the fiber. In that case the differential normal and tangential forces (dF_S and dF_L) at any point are given by the following equations:

$$dF_s = dF \sin \alpha$$

and,

$$dF_L = dF \cos \alpha$$

The resulting strain dy in the y direction is

$$dy = ds \sin \alpha + dL \cos \alpha$$

The cantilever beam formula gives:

$$ds = \frac{dF_s (L/2)^3}{E_o K^2 \pi a^2/4}$$

where K is the radius of gyration of the cross section of the fiber about its neutral axis. Then,

$$dL = \frac{1}{E_o} \frac{(L/2) dF_L}{\pi a^2/4}$$

and

$$\frac{dy}{dF} = \frac{(L/2)^3}{E_o K^2 \pi a^2/4} \sin^2 \alpha + \frac{L/2}{E_o \pi a^2/4} \cos^2 \alpha$$

Let E' be the apparent modulus of elasticity of the model made up of curled fibers. Then,

$$\frac{1}{E'} = \frac{dy}{dF} \frac{\text{area of model}}{\text{length of model}}$$

or,

$$\frac{1}{E'} = \frac{2aL}{L/2} \left[\frac{(L/2)^3}{E_o K^2 \pi a^2/4} \sin^2 \alpha + \frac{L/2}{E_o \pi a^2/4} \cos^2 \alpha \right]$$

Let $\cos^2 \alpha = 1$ and $\sin^2 \alpha = L^2/4R^2$. Then,

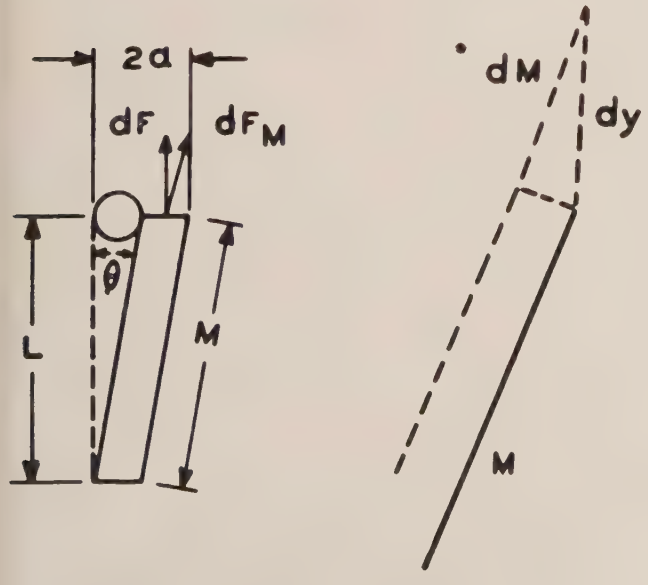

Fig. 9

$$\frac{1}{E'} = \frac{2L^5}{4E_o K^2 R^2 \pi a} + \frac{8L}{E_o \pi a}$$

After substitution of

$$\frac{1}{E} = \frac{8L}{E_o \pi a} \quad \text{(from text)}$$

$$\frac{1}{E'} = \frac{L^4}{16ER^2K^2} + \frac{1}{E}$$

Then,

$$E' = E \frac{16R^2K^2}{L^4 + 16R^2K^2}$$

or,

$$E' = E \frac{1}{1 + (L^4/16R^2K^2)}$$

APPENDIX B

The accompanying illustration represents a model having a fiber section with a component of direction normal to the plane of the surface of the paper. The length of the section is

$$M = \frac{L}{\cos \theta}$$

where L is the length in the y direction.

An increment of force, df_M, applied parallel to the axis of the section produces an increase in length, dM. These quantities are related as follows:

$$\frac{df_M}{dM} = E_o \frac{\pi a^2}{4M}$$

But

$$dM = dy \cos \theta$$

where dy is the displacement of the end of the section in the y direction (see illustration), also,

$$df_M = \frac{df}{\cos \theta}$$

where df is the y component of force df_M. Therefore:

$$\frac{df}{dy} = E_o \frac{\pi a^2}{4L} \cos^3 \theta$$

$$E = \frac{df}{dh} \frac{\text{length of model}}{\text{area of model}}$$

$$= E_o \frac{\pi a^2}{4L} \cos^3 \theta \frac{L}{2aL}$$

$$= E_o \frac{\pi a}{8L} \cos^3 \theta$$

$$= E_o \frac{\pi a}{8L} \frac{L^3}{(a^2 + L^2)^{1.5}}$$

An expression for density of this model is developed as follows, assuming that the model contains two fiber sections:

$$d = d_o \frac{2\pi a^2 M}{4}$$

$$= d_o \frac{\pi a}{4L} \frac{1}{\cos \theta}$$

$$= d_o \frac{\pi a}{4L} \frac{(a^2 + L^2)^{1/2}}{L}$$

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Chemical Reaction Equilibria in Calcium and Magnesium-Base Sulphite Recovery Systems

ROY P. WHITNEY, RICHARD M. ELIAS, and MALCOLM N. MAY

Many sulphite pulp mills are considering possible systems of utilizing or disposing of spent sulphite liquor involving evaporation and burning. From the standpoint of recovery and reuse of inorganic chemicals in pulping, it is desirable that information be at hand regarding the chemical compounds which are formed in the recovery furnace, and regarding the effect of combustion conditions upon the extent to which each may be present. This paper presents the results of calculations of chemical reaction equilibria for many of the important reactions which may be involved in the combustion of calcium-base and magnesium-base spent sulphite liquor. The calculations have been based upon thermodynamic data for the several compounds of interest, compiled from the literature. They indicate the conditions under which the oxide, sulphide, or sulphate of calcium or magnesium might be expected to predominate, and suggest a possible explanation for the observed differences in composition of the ash from calcium-base and magnesium-base liquor combustion.

THE utilization or disposal of spent sulphite liquor presents problems of some magnitude. In spite of the considerable research effort which has been directed toward this end, there is yet no generally applicable system or process which has had wide acceptance. It is probably safe to say, however, that the closest approach to an industry-wide solution to the sulphite liquor problem consists of (or at least involves) evaporation and burning.

Because of certain advantages to be gained in the pulping operation and in evaporation and burning, considerable interest is being shown in the use of bases other than calcium. Since these other bases are all more costly than lime or limestone, their recovery and reuse become of correspondingly greater importance. In the combustion of magnesium-base liquor under proper conditions it has been shown to be possible to recover the base principally as magnesium oxide, a compound which may be directly reused to produce cooking acid.

Even though the recovery and reuse of cooking chemicals are of less economic significance in the case of calcium-base liquor, there is nevertheless considerable interest in burning this liquor. It follows, therefore, that the resulting ash must be collected and either utilized or disposed of, and its chemical composition becomes of interest. There appears to be a major difference in the behavior of the calcium and magnesium-base systems at combustion temperatures, since combustion of the calcium-base liquor under the usual conditions fails to yield the oxide in appreciable proportions.

Fundamentally, the composition of the ash resulting from such combustion operations as are being discussed depends upon two factors: the equilibrium conditions for the several reactions which may simultaneously occur, and the rates at which these reactions proceed. To a considerable extent, the rate factor is under the control of the furnace designer since he can provide an adequate combustion volume to allow time for the reactions to proceed (provided, of course, that the required volume is within reason). The factor of equilibrium is somewhat beyond his control, however, except insofar as he can control the conditions which affect the equilibrium. These principal conditions are the ratios of the various reactants and the temperature of the operation.

Utilizing thermodynamic data assembled from the literature, it has been possible to calculate an index of equilibrium for many of the reactions believed to be of importance in fixing the ash composition from the combustion of either calcium or magnesium-base liquor. It is the object of this paper to present the results of these calculations and to discuss their significance.

EQUILIBRIUM CALCULATIONS

Spent sulphite liquor from calcium or magnesium-base pulping is an aqueous solution containing calcium or magnesium lignosulphonate, sugars and related compounds, sulphur dioxide, various inorganic sulphur compounds, and other miscellaneous organic sulphur compounds. Although the composition changes somewhat upon evaporation, the concentrated liquors fed to the recovery furnace may also be characterized in these general terms. If the liquor is burned with air to the practical elimination of organic matter, the resulting chemical system may consist of a mixture of certain of the elements carbon, hydrogen, oxygen, sulphur, and either calcium or magnesium, and the possible inorganic compounds of these elements. As has been noted, if a sufficient combustion space volume is provided to permit all possible chemical reactions among these components to proceed as far as they will, then an insight into the composition of the gas-solid mixture leaving the combustion space can be gained by studying these chemical reactions and their equilibria.

The principles of chemical reaction equilibrium are thoroughly discussed in many textbooks on physical chemistry and thermodynamics (*1*, *2*), and need only be briefly reviewed here. Consider a reversible chemical reaction such as the reduction of carbon dioxide with carbon:

$$C(s) + CO_2(g) = 2CO(g) \qquad (1)$$

This reaction will proceed, at some fixed temperature and pressure, until a certain ratio of reactants to products is reached, after which no further change will take place (unless the reaction conditions are altered). The

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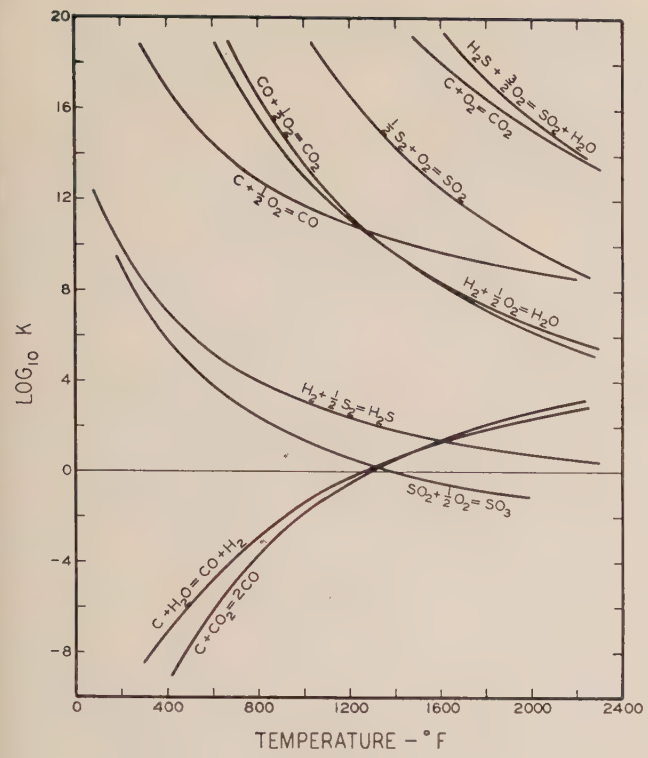

Fig. 1. Equilibrium constants for selected combustion reactions

reaction is said to have reached equilibrium, and this state is defined by the equilibrium constant K,

$$K = \frac{(a_{CO})^2}{(a_C)\,(a_{CO_2})} \qquad (2)$$

where a_{CO} represents the activity of carbon monoxide in the equilibrium mixture, and so on. The activity of the pure solid may be taken as equal to unity, and if the total pressure is one atmosphere, the activities of the gases will be nearly equal to their partial pressures. Thus,

$$K \cong \frac{(p_{CO}/P)^2}{(p_{CO_2}/P)} \qquad (3)$$

Evidently a knowledge of the constant K at the temperature of interest will permit calculation of the ratio of the partial pressures of carbon monoxide and carbon dioxide at equilibrium.

Values for the equilibrium constant K are determined from the standard free energy change for the reaction, according to the relation

$$\Delta F^\circ = -RT \ln K \qquad (4)$$

where R is the gas constant and T is the absolute temperature. The standard free energy change is, in turn, related to the enthalpy change (the heat of reaction at constant pressure) and the entropy change for the reaction, as follows:

$$\Delta F^\circ = \Delta H^\circ - T\Delta S^\circ \qquad (5)$$

(All changes in thermodynamic properties are referred to the standard states of the reacting components.) Thus, for calculation of the equilibrium constant, the standard enthalpy and entropy changes, or the free energy change, for the reaction must be known at the desired temperature.

Obviously, the state of a reacting system of several components, such as those systems being considered here, cannot be defined by one chemical reaction Many chemical reactions may be proceeding simultaneously and a sufficient number of these reactions to define the system must be considered. In general, this required number is at least equal to the number of components which may be expected to coexist at equilibrium. In addition, it may be desirable to consider other reactions which can be derived from the primary group. Equilibrium for the system is realized when the activities of all existing components are such as to satisfy the equilibrium constants for all possible reactions. These activities are determined by simultaneous solution of the equilibrium expressions for the required numbers of reactions. Although the case of several simultaneous reactions is no more complex in theory than that of a single reaction, the simultaneous solution of the equilibrium expressions to determine the activities of the reacting components may become well-nigh impossible.

For the case at hand, two systems were considered, one for calcium base and one for magnesium base. A group of primary reactions, at least sufficient in number to define each system, was then evolved. The following basic reactions were common to both systems:

(1) $C(s) + {}^1/_2O_2(g) = CO(g)$
(2) $C(s) + O_2(g) = CO_2(g)$
(3) $H_2(g) + {}^1/_2O_2(g) = H_2O(g)$
(4) $H_2(g) + {}^1/_2S_2(g) = H_2S(g)$
(5) ${}^1/_2S_2(g) + O_2(g) = SO_2(g)$
(6) $SO_2(g) + {}^1/_2O_2(g) = SO_3(g)$

For the calcium-base system, the following reactions were added:

(7) $CaCO_3(s) = CaO(s) + CO_2(g)$
(8) $CaSO_4(s) = CaO(s) + SO_2(g) + {}^1/_2O_2(g)$
(9) $CaS(s) + 2O_2(g) = CaSO_4(s)$
(10) $CaS(s) + H_2O(g) = CaO(s) + H_2S(g)$

The corresponding magnesia-base equations were:

(11) $MgCO_3(s) = MgO(s) + CO_2(g)$
(12) $MgSO_4(s) = MgO(s) + SO_2(g) + {}^1/_2O_2(g)$
(13) $MgS(s) + 2O_2(g) = MgSO_4(s)$
(14) $MgS(s) + H_2O(g) = MgO(s) + H_2S(g)$

Many additional reactions can be derived by adding and subtracting those given above. The following derived reactions were considered worthy of inclusion:

(15) $CO(g) + {}^1/_2O_2(g) = CO_2(g)$
(16) $C(s) + H_2O(g) = CO(g) + H_2(g)$
(17) $C(s) + CO_2(g) = 2CO(g)$
(18) $H_2S(g) + {}^3/_2O_2(g) = SO_2(g) + H_2O(g)$
(19) $CaS(s) + {}^3/_2O_2(g) = CaO(s) + SO_2(g)$
(20) $CaSO_4(s) + C(s) = CaO(s) + SO_2(g) + CO(g)$
(21) $CaSO_4(s) + 2\,C(s) = CaS(s) + 2CO_2(g)$
(22) $MgS(s) + {}^3/_2O_2(g) = MgO(s) + SO_2(g)$
(23) $MgSO_4(s) + C(s) = MgO(s) + SO_2(g) + CO(g)$
(24) $MgSO_4(s) + 2C(s) = MgS(s) + 2CO_2(g)$

Standard heats of formation and absolute entropies are available for many elements and compounds at 25°C. These data are reproduced in Table I, for the components of interest. They have been taken, where possible, from the recent compilation of the National Bureau of Standards (*3*). Since both enthalpy and entropy are point functions, it is possible to add and subtract these values to obtain the standard enthalpy and entropy changes for any given reaction at 25°C. These values may then be combined through equation (5) to yield the standard free energy change for the reaction, and from this the equilibrium constant is calculated (equation (4)). These equilibrium constants at 25°C. (298.16°K.) for the 14 primary reactions are presented

in the first column of Table II. Because of the great range of the numerical values, it is convenient to record the logarithm of the constant rather than the constant itself.

Table I. Heats of Formation and Entropies of Elements and Compounds, at 298.16°K. (25°C.)[a]

	ΔH_f°	S°
	cal./(g.-mole)	*cal./(g.-mole)(°K.)*
C(s) (β graphite)	0	1.36
O_2(g)	0	49.00
H_2(g)	0	31.21
S_2(g)	+29,860	54.41[b]
CO(g)	−26,416	47.30
CO_2(g)	−94,052	51.06
H_2O(g)	−57,798	45.11
H_2O(g)	−4,815	49.15
S_2S(g)	−70,960	59.40
SO_3(g)	−94,450	61.24
$CaCO_3$(s) (calcite)	−288,450	22.2
CaO(s)	−151,900	9.5
$CaSO_4$(s) (anhydrite)	−342,420	25.5
CaS(s)	−115,300	13.5
$MgCO_3$(s)	−266,000	15.7
MgO(s)	−142,950	6.66
$MgSO_4$(s)	−305,500	21.9
MgS(s)	−83,000	10.6[c]

[a] Except where noted, data are from National Bureau of Standards (*3*).
[b] Entropy of S_2(g) from Kelley (*4*).
[c] Entropy of MgS(s) from Kapustinskiĭ and Korshunov (*5*).

Extension of the equilibrium calculations to higher temperatures requires a knowledge either of the high-temperature enthalpies and entropies of the elements and compounds, or data on their heat capacities as functions of temperature. Kelley (*6*) has calculated and compiled many data on high-temperature enthalpies and entropies, and his data were used wherever possible. Kelley gives no high-temperature data for calcium sulphide, magnesium sulphate, and magnesium sulphide, but in another publication (*7*) he has estimated empirical heat capacity equations for two of these compounds, as follows:

CaS: $C_p = 10.20 + 3.80 \times 10^{-3}T$ cal./(g.-mole) (°K.)
$MgSO_4$: $C_p = 21.90 + 14.35 \times 10^{-3}T$ cal./(g.-mole) (°K.)

The heat capacity of magnesium sulphide was estimated in the manner suggested by Kapustinskiĭ and Korshunov (*5*) for this compound. The quantity ΔC^p (heat capacity of the product minus the heat capacities of the reactants) was assumed to be the same for the formation of magnesium sulphide as for the formation of calcium sulphide from the elements. Knowing ΔC^p and the heat capacities of magnesium and rhombic sulphur (*6*), the heat capacity of magnesium sulphide was estimated as:

MgS: $C_p = 11.10 + 1.80 \times 10^{-3}T - 0.78 \times 10^5 T^{-2}$ cal./(g.-mole) (°K.)

High-temperature enthalpies and entropies for the latter three compounds were calculated from these heat capacity equations using the relations

$$H_T - H_{298.16} = \int_{298.16}^{T} C_p\, dT \qquad (6)$$

$$S_T - S_{298.16} = \int_{298.16}^{T} \frac{C_p}{T}\, dT \qquad (7)$$

The calculated values for $\log_{10} K$ at the selected high temperatures are presented in Table II.

Values for $\log_{10} K$ for the derived equations are not shown in tabular form. They may be obtained by adding or subtracting $\log_{10} K$ for appropriate primary reactions. Consider, for example, reaction 21:

$$CaSO_4(s) + 2C(s) = CaS(s) + 2CO_2(g)$$

This reaction may be derived by subtracting reaction 9 from twice reaction 2:

$$\begin{array}{r} 2C(s) + 2O_2(g) = 2CO_2(g) \\ -[CaS(s) + 2O_2(g) = CaSO_4(s)] \\ \hline CaSO_4(s) + 2C(s) = CaS(s) + 2CO_2(g) \end{array}$$

$$K_{21} = \frac{(K_2)^2}{K_9}$$

$$\log_{10} K_{21} = 2 \log_{10} K_2 - \log_{10} K_9$$

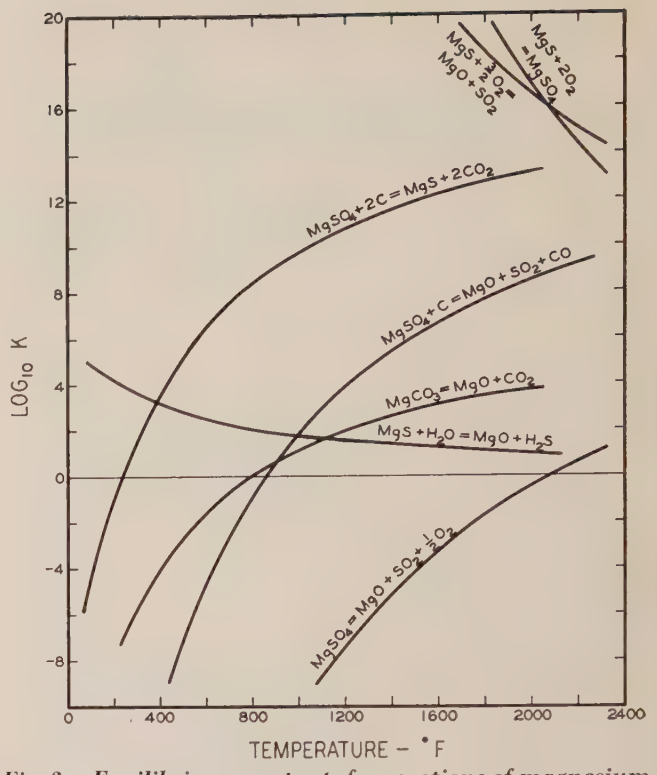

Fig. 2. Equilibrium constants for reactions of magnesium compounds

Obviously, the calculated equilibrium constants can be no more reliable than the thermal data on which they are based. All the data at 25°C. are believed to be sound with the possible exception of the entropy of magnesium sulphide, and this can hardly be seriously in error. High-temperature data for the gaseous constituents are probably highly accurate. The least satisfactory data are those represented by the heat capacity equations for calcium sulphide, magnesium sul-

Table II. $\log_{10} K$ for Primary Reactions

Reactions	*298.16°K.*	*500°K.*	*800°K.*	*1200°K.*	*1500°K.*	*Reference*
1	24.0	16.3	11.9	9.5	8.5	(*3*)
2	69.1	41.3	25.8	17.2	13.8	(*3*)
3	40.0	22.9	13.3	7.9	5.7	(*3*)
4	12.4	6.6	3.2	1.3	0.5	(*3, 4, 6*)
5	59.3	33.8	19.8	11.8	8.8	(*3, 4, 6*)
6	12.4	5.3	1.5	−0.5	...	(*3, 6*)
7	−22.7	−10.2	−3.4	0.3	1.9	(*3, 6*)
8	−72.7	−37.4	−17.9	−7.4	−3.2	(*3, 6*)
9	147.5	80.4	43.2	22.8	14.7	(*3, 6, 7*)
10	−12.0	−7.1	−4.5	−3.0	−2.4	(*3, 6, 7*)
11	−12.1	−3.5	1.1	3.4	...	(*3, 6*)
12	−52.2	−25.1	−10.3	−2.3	0.8	(*3, 6, 7*)
13	144.1	78.3	41.9	21.9	14.1	(*3, 5, 6, 7*)
14	5.1	3.0	1.8	1.2	0.9	(*3, 5, 6*)

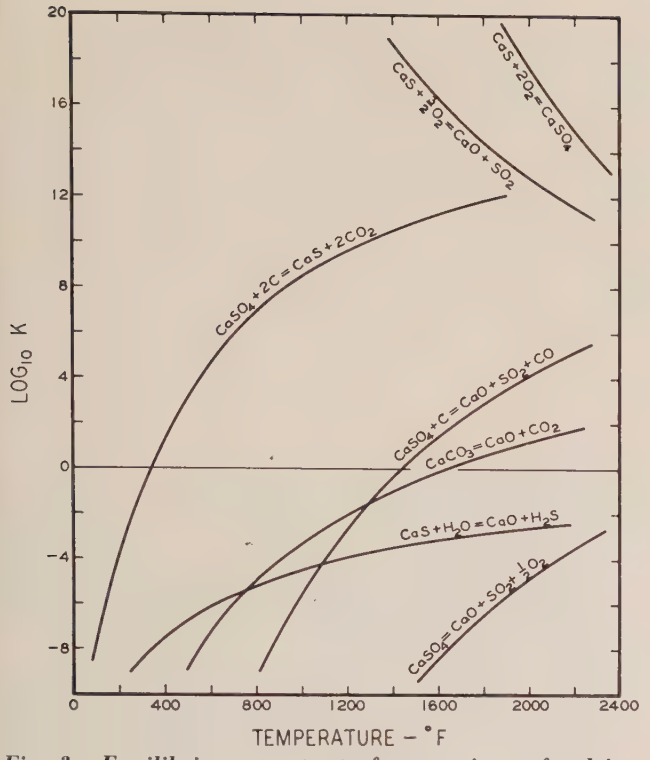

Fig. 3. Equilibrium constants for reactions of calcium compounds

phate, and magnesium sulphide, with the latter undoubtedly the most questionable. It is believed, however, that all the data are adequate for the purpose at hand.

DISCUSSION

All calculated equilibrium constants are shown graphically in Figs. 1, 2, and 3, as functions of temperature. Figure 1 shows some of the important combustion reactions involving carbon, hydrogen, and sulphur; Fig. 2 shows selected reactions of magnesium compounds, and Fig. 3 is devoted to calcium compounds.

No attempt has been made to solve simultaneously the equations represented by these equilibrium constants in order to obtain the activities (partial pressures) of each reacting gaseous component at equilibrium. Such solutions would be extremely tedious to obtain, they would have to be repeated for each temperature and reactant ratio (liquor composition and quantity of air used in combustion) of interest, and they are not essential to an understanding of the behavior of the systems under any given set of conditions. For example, the data in Fig. 1 show that, at a temperature of 2000°F., a fuel consisting of carbon, hydrogen, and sulphur will burn under oxidizing conditions (an excess of air) to yield carbon dioxide, water, and sulphur dioxide, mixed, of course, with the excess oxygen and the nitrogen. Under the same oxidizing conditions, but at 600°F., the sulphur dioxide would have oxidized to sulphur trioxide. At 2000°F., but under reducing conditions (a deficiency of air), not only carbon dioxide, water, and sulphur dioxide, but also carbon monoxide, hydrogen, sulphur gas, and hydrogen sulphide would be present; the exact ratio between the reduced and the oxidized forms would depend upon the individual equilibria and the actual quantity of oxygen supplied. Essentially no oxygen would be present in the equilibrium mixture. Under reducing conditions but at 600°F., the carbon monoxide would have reacted with hydrogen or decomposed to deposit carbon and yield water and carbon dioxide, and the hydrogen and sulphur gas would have reacted to form hydrogen sulphide to the practical elimination of the lesser constituent. These equilibria, although well known, have been included for purposes of illustration, and because they are essential to the following considerations.

Equilibrium constants for the selected reactions involving magnesium compounds are shown in Fig. 2. The result of combustion under reducing conditions is illustrated by the two reactions involving magnesium sulphate and carbon. The reaction products differ depending upon the quantity of carbon present, but both reactions proceed strongly to the right at elevated temperatures. With an excess of carbon, as would be present if a thick fuel bed were maintained, the principal product would be expected to be magnesium sulphide.

Under oxidizing conditions, Fig. 2 indicates that magnesium sulphide is very strongly oxidized to magnesium sulphate. Combustion, under expected recovery furnace conditions, at temperatures below about 1600°F. should yield magnesium sulphate almost exclusively. However, at temperatures above about 1600°F., magnesium sulphate thermally decomposes into magnesium oxide, sulphur dioxide, and oxygen, the equilibrium becoming progressively more favorable as the temperature is increased. It is believed to be largely this thermal decomposition which makes possible the recovery of magnesium oxide from sulphite liquor combustion.

The reaction of magnesium sulphide with water is also interesting. The equilibrium is slightly favorable at all temperatures shown, and the reactions would be forced further to the right by combustion (and thus removal) of the hydrogen sulphide formed.

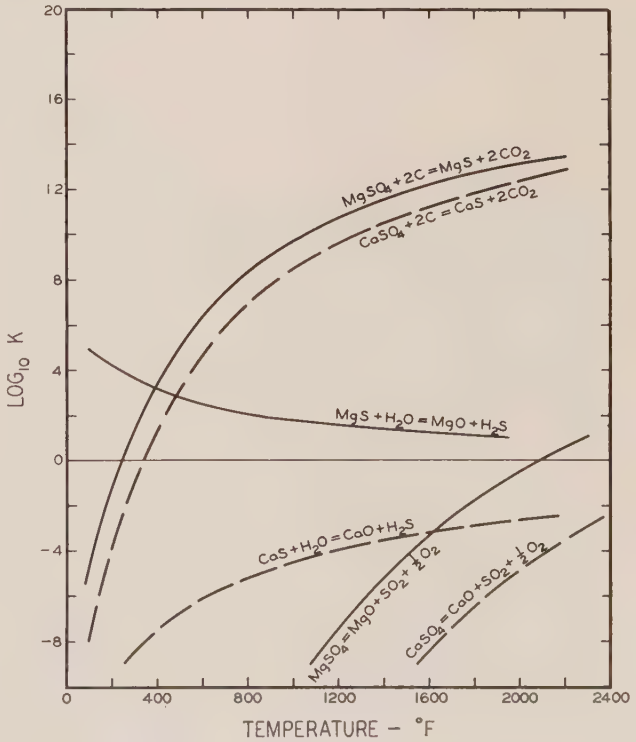

Fig. 4. Comparison of equilibrium conditions for reactions of calcium and magnesium compounds

Equilibrium for the corresponding reactions of calcium compounds is shown in Fig. 3. In general, the pattern is similar to that for the magnesium compounds. Under reducing conditions, calcium sulphide should be the principal product and under oxidizing conditions, calcium sulphate is formed. Two outstanding differences between this system and the magnesium system are noted. First, and probably most important, the thermal decomposition of calcium sulphate occurs at a considerably higher temperature than in the case of magnesium sulphate. Under furnace conditions, it is indicated that temperatures above about 2300°F. would be required for this decomposition. The second difference lies in the reaction of calcium sulphide with water to form calcium oxide and hydrogen sulphide. Equilibrium for this reaction is considerably less favorable than for the corresponding magnesium reaction. This reaction, nevertheless, may proceed to some extent if the hydrogen sulphide is thoroughly removed by combustion. At temperatures below about 2300°F., any lime so formed would tend to revert to calcium sulphate so long as sulphur dioxide and oxygen were present. These differences between the magnesium and the calcium systems are better illustrated in Fig. 4.

The thermal decomposition of calcium sulphate has been observed experimentally by Curti (*8*), who heated pure calcium sulphate for various times at various temperatures . Decomposition into the oxide was noted between temperatures of 2400 and 3200°F., the extent depending on the time and the temperature.

Normally, the combustion gases leaving the furnace pass through a boiler section, there undergoing a gradual reduction in temperature. It is pertinent, therefore, to inquire into the shifting of the equilibria which have been discussed, as the temperature is lowered. Such shifts, which undoubtedly occur to some extent, will be toward the conversion of the oxide of calcium or magnesium into the sulphate, an undesirable circumstance. Obviously, the temperature lowering should be less harmful in the case of the magnesium system. That the conversion apparently does not take place to a serious extent in this instance must be attributed to the limiting effect of the reaction rates.

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Description and Action of the Morden "Slush-Maker" Pulper

BURKE MORDEN

The "Slush-Maker" pulper quickly and efficiently gives the initial disintegration to pulp or paper stock. In addition, through a handwheel-controlled bar-to-bar setting, difficult flakes and bundles are readily brushed out of the stock, color and other additives mixed and brushed in, furnishes blended, and, if desired, given a preliminary beating treatment, either on a continuous or batch basis. Tests run with the pilot machine show that the "Slush-Maker" completely defibers high wet-strength papers, even in cold water, without damaging the fiber.

The Morden "Slush-Maker" for pulping, mixing and preliminary beating was conceived by C. W. Morden, President of Morden Machines Co., as a logical and desirable addition in the stock preparation field.

Some 15 years ago his conception of continuous beating and refining with the "Stock-Maker" efficiently and effectively replaced the beating function of the beater. Now the "Slush-Maker" has been designed to replace the beater's functions of pulping, breaking, slushing, mixing, brushing-out and giving a light preliminary treatment to various pulp furnishes either on a continuous or batch basis, prior to subsequent treatment in "Stock-Makers" or other beating and refining equipment.

Burke Morden, Vice-President, Morden Machines Co., Portland, Ore.

During the design and development of this unit over the last 5 years, many other pulping units have been introduced into the field. However, the "Slush-Maker" embodies principles that differ from these units. The theory underlying the "Slush-Maker's" development is that a pulping unit must not only quickly and efficiently give the initial disintegration to the material, but that once this point is reached, the action of the unit must be easily controllable so that the remaining flakes and bundles can be readily brushed out of the stock, color and other additives mixed and brushed in, furnishes blended, and, if desired, given a general preliminary treatment.

To accomplish this variety of purposes it was determined that some controllable bar-to-bar action was essential. In the "Slush-Maker" there is not only a disintegrating rotor but in addition this rotor can be ad-

justed, by a handwheel setting, to work against an attritioning ring. By this means bar-to-bar setting for a variety of treatments can be adjusted or maintained as simply as in a beater or refiner.

To adequately study the action of these principles on a wide variety of materials under various conditions, a pilot machine was built with a 17-inch rotor which handles between 50 and 225 pounds of air-dried stock with consistencies between 3 and 7%, shaft speeds between 380 and 710 rpm, motor powers from $6^1/_2$ to 45 hp., defibering times from 2 minutes to 4 hours, and daily capacities from 1 ton up to 6 or 8 tons depending on the type of service.

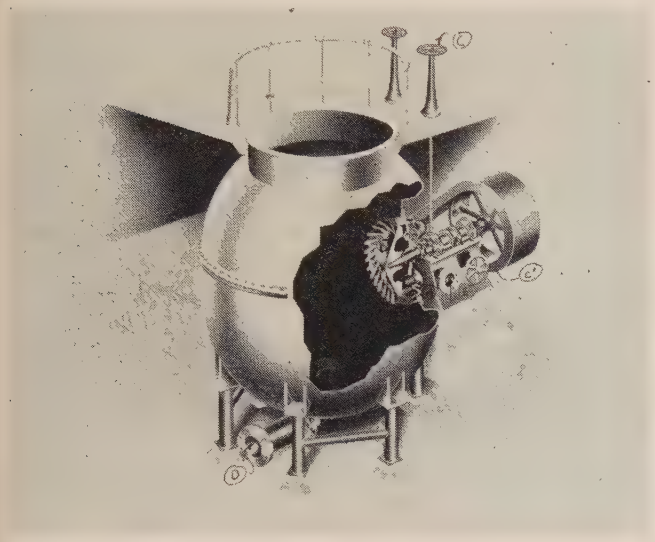

Fig. 1

The cutaway view, Fig. 1, shows the "Slush-Maker" as it is being built commercially having basically a cylindrical tank with a hemispherical bottom. This tank can be fabricated of steel, tile, or other materials. Various shapes and proportions for the tank have been explored and tried and this form appears to be as simple and effective as any.

Into one side of the tank, just above the hemispherical bottom, is mounted the stationary shearing, impingement, and attritioning ring (A). This has a conically shaped attritioning surface which surrounds the rotor and is grooved to form the equivalent of bars. In addition it has peripheral shearing teeth so beveled that tramp material will be thrown off and not locked with the disintegrating rotor.

A horizontal shaft assembly extends into the tank, through the stationary impingement ring, and carries the conical rotor hub (B) inside the tank. Pronglike shredding blades extend from the periphery of this rotor hub for initially shredding and breaking up the charge of pulp. The section of each of these blades is U shaped forming in effect two bars on the back side. The study of various rotor patterns shows this simple, clean-cut form to be very effective for all types of operation.

The shaft assembly, outside of the tank, consists of a one-piece bearing cartridge enclosing both the thrust and radial bearings, mounted on a rigid stand with provisions for either a belt or direct drive.

The whole shaft assembly and bearing cartridge is adjustable longitudinally by either of the handwheels (C or C′), through a worm gear, so that the bar surfaces on the back side of the shredding blades on the rotor may be adjusted to any desired clearance from the bars on the face of the stationary impingement ring.

With a substantial clearance between these bars, the action of the machine is limited to breaking up, shredding, and disintegrating the material as in most conventional pulpers. By setting up the handwheel to bring these bar surfaces closer together, the bars serve to completely debundle more difficult material, and when set up hard, give in addition a very definite brushing type treatment to the individual fibers.

The flow of the stock in the unit is such that the pumping action, set up by the blades on the rotor, draws the stock to the rotor where large pieces are shredded or broken by the shredding blades assisted by the shearing teeth on the periphery of the attritioning ring. Once the pieces are broken down sufficiently to pass between the shredding blades they impinge against the stationary attritioning ring and can be brushed by the two opposing sets of bars.

The "Slush-Maker" can be operated either batch or continuous. For batch operation the completed charge is drawn out of the bottom of the tank at (D). For continuous operation the disintegrated material can be drawn off either by a screened opening in the side of the tank or from behind the rotor at (E) where the disintegrated stock enters through the narrow clearance between the rotor and the attritioning ring.

Devices are being developed for separating and removing tramp material during the pulping process.

Trial runs were made with the pilot machine to determine how the variables of charging procedure, rotor design, shaft speed, consistency, tank size and stock level, bar setting, and water temperature affected the power and labor per ton required to obtain satisfactory defibering.

A standard furnish of waste news in cold water, without any additives, was used in the trials.

To provide a standard for comparing the degree of defibering, a "breaking index" was established for grading the handsheets from initial disintegration up to complete defibering.

OPERATION OF EQUIPMENT

The results of these trials followed the general pattern that would be expected and are briefly summarized below:

Charging. After the tank was filled with water, it made no difference whether the news was charged in tied or broken bundles, either before or after the mechanical unit was started. On other furnishes, even in this relatively small unit, full size pulp sheets or baled charges of broke could be added without any special preparation. Rolls could be allowed to spin themselves in, or charged in full rolls, all of which worked satisfactorily.

Rotor Design. A smooth-faced rotor cone, inside the radius of the shredding blades, as shown, eliminated all plugging tendency under normal operating conditions as compared with a rough patterned face on the rotor. To test the effect of tramp material on the working elements a miscellaneous assortment of scrap metal, wires, tin cans, nails, and chunks of wood was thrown in and

none of these had any detrimental effect on the working elements.

Speed. Increasing rotor speed decidedly decreased the breaking time while only slightly increasing the power per ton, and decidedly decreasing the labor per ton.

Consistency. Increasing consistency slightly decreases the power per ton, decidedly decreases the labor per ton, and only slightly increases the breaking time.

Tank Sizes and Stock Levels. Increasing the level of the stock above the rotor and increasing the volume of the tank decreased the power per ton and substantially increased the daily capacity, thus further reducing the labor per ton.

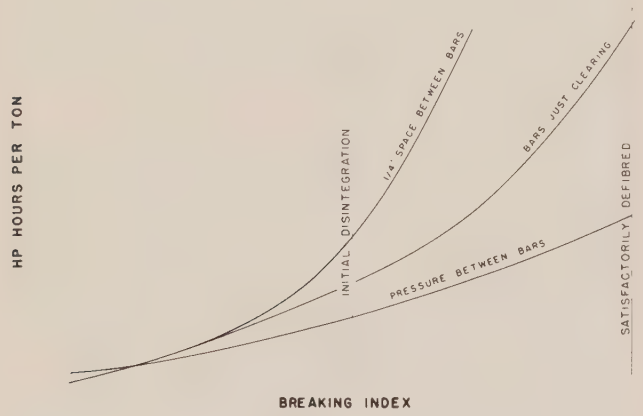

Fig. 2. Effect of bar settings on degree of defibering in Morden "Slush-Maker" pulper. (Waste news in cold water)

Hot Water. Raising the water temperature very decidedly speeded up the breaking time and decreased the power per ton, thus again increasing the daily capacity and reducing the labor per ton sufficiently to much more than offset the cost of the hot water.

Bar Settings. Setting the bars of the disintegrating rotor at various clearances from the bars on the attritioning ring had a decided effect on the efficiency of disintegration as shown in Fig. 2. It will be noted that with the bars clearing by $^1/_4$ inch, or with the blades just breaking and circulating the stock, that the least breaking index point is reached. With the bars just clearing, a satisfactory defibering is achieved, but with pressure between the bars the same defibering is achieved at about one half the power per ton, with almost a straight-line development. The motor power with $^1/_4$-inch space between the bars is about 20% less than with the "bars just clearing." From "just clearing" to "pressure between the bars" increases the motor power only about 1%. By satisfactory defibering is meant the clearing of the stock to the point where only a few pinhead size specks remain which will easily disappear through any subsequent beating or refining treatment. These will also disappear with a slight additional time in the "Slush-Maker." This well proves the advantages of having a controllable bar-to-bar action to achieve complete defibering in a pulper.

Circulation. Under all normal operating conditions the circulation is good. The whole interior of the tank is scoured, with no place for stock to lodge. The flow wells up around the outer edges of the tank, with no appreciable splashing, and goes down near the center, giving good submergence. Slow speeds, at large tank volumes or heavy consistencies, will decrease the circulation, but so long as conditions are maintained which give circulation of all the stock, complete defibering can be obtained under a great variety of conditions.

Labor and Power. In studying the relation between labor and power costs per ton it was noted that the labor per ton decreased very decidedly as the daily capacity was increased, and that the labor cost compared very favorably with any modern pulping unit that can be quickly charged and emptied. The power per ton remains fairly constant under a wide variety of operating conditions, being affected mostly by water temperature.

Average Operating Condition. To arrive at an average operating condition, giving the best balance between labor and power on a cost per ton basis, it was found most efficient to operate at relatively high speed, maximum tank volume, medium consistency, and light bar pressure. For easy breaking applications, the speed can be reduced or the consistency increased to establish a convenient time cycle. On hard breaking applications, increasing the speed and consistency is advantageous. Under all conditions, raising the water temperature further improves the efficiency.

Various Papers and Pulps. As a basis of comparison, on various papers and pulps satisfactorily defibered to the point where only a few pinhead size specks remain,

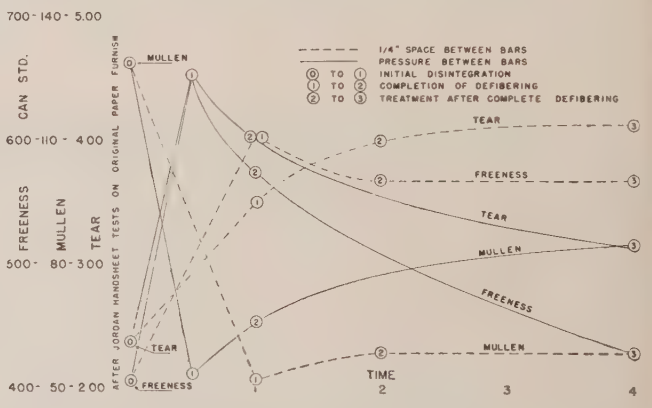

Fig. 3. Effect of bar settings on defibering and treatment in Morden "Slush-Maker" pulper. (A high wet-strength kraft in hot water with alum)

which is beyond the point normally anticipated from most pulping equipment, the "Slush-Maker" required the following power per ton:

Waste news:
- In 55° water from 60 to 80 kw.-hr.
- In 150° water from 20 to 25 kw.-hr.

Purchased pulp:
- In 55° water from 15 to 50 kw.-hr. depending upon the type of drying

Kraft waste made up of heavy wrappings, liners, gummed tape, etc.:
- In 55° water approximately 120 kw.-hr.
- In 130° water approximately 60 kw.-hr.

At a 5 mill per kw.-hr. rate these figures range from 10 to 60¢ per ton.

ACTION ON WET-STRENGTH BROKE

In checking with various mills for other material to test in the unit everyone said "what will it do on wet strength?" In order to find out, two mills sent us their high wet-strength broke which they had been unable to satisfactorily pulp in any of their present-day pulping equipment and, as a result, were burning this broke. This material, containing 2 to $2^1/_2$% melamine resin, had seasoned more than a month. One was a 50-pound semibleached kraft liner and the other was a greaseproof.

The following report is on the kraft; the greaseproof followed a similar pattern.

In a series of tests using 120 to 200° water, consistencies between 4 and 6%, from no alum up to 90 pounds of alum per ton, and speeds from 550 up to 710 r.p.m., this high wet strength was satisfactorily defibered at figures of from 820 to 220 kw.-hr. per ton. Even in 55° water with no alum, which might be considered the acid test on any piece of pulping equipment, it was satisfactorily defibered for about 1700 kw.-hr. per ton.

Using the most efficient operating conditions for balancing steam, power, and alum costs gives a pulping cost per ton figure, without labor, of about $5. Depending on the capacity of the unit, the labor costs would run from $3 per ton for a 6 ton per day unit up to about $12 for the pilot machine which has capacity of $1^1/_2$ tons per day in this type of service. This gives a total cost per ton of from $8 to $17 depending upon conditions.

Assuming that this high wet strength, that would otherwise be burned, is worth $100 per ton as pulp, and

Fig. 4

taking a generous total pulping cost per ton of $15, and figuring salvaging only 1 ton per day, this would mean a monthly saving of at least $2500 per month or $30,000 per year.

With a unit that will give this type of service on nearly impossible material, it stands to reason that it is equally efficient on easier breaking material.

The next item to determine was the type of treatment the bar action was giving. For convenience the same semibleached kraft wet-strength broke was used. Figure 3 shows very decidedly the variations in breaking time and treatment that are given by two extremes in bar settings. With $^1/_4$-inch space between the bars, as

Fig. 5

shown by the broken lines, the time for initial disintegration (0 to 1) and complete defibering (1 to 2) takes twice as long, and after the completion of defibering, the tear, burst, and freeness curves (2 to 3) flatten out showing no further appreciable treatment on the fiber. With pressure between the bars, as shown by the solid lines, the initial disintegration (0 to 1) and complete defibering (1 to 2) take only half as long and after the completion of defibering (2 to 3), there is a continuing tear, burst, and freeness development. At the completion of defibering and even at the completion of the treatment, the test figures are safely above the handsheet tests taken on the original paper furnish at the jordan headbox, before the addition of white water.

Figure 4 shows a photomicrograph of this stock, run with bar pressure, at the completion of defibering. Figure 5 shows the same stock at the completion of the treating cycle. These show a brushed fiber, with little or no cutting and well prepared to blend into any furnish. Further treatment of this repulped material in a laboratory beater develops higher tear and lower burst, at a given freeness, than was developed in its first treatment to the paper machine.

Based upon the experience with the pilot machine, we are currently building larger units to handle from 750 to 1750 pounds of stock, or up to 30 or more tons per day, which embody all of the basic features outlined herein. The operation of these units will add to the data already accumulated so that it will be possible to construct even larger pulpers.

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The Permeation of Vapors Through Polyethylene

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The data in this report are limited to the vacuum permeation of a number of vapors through polyethylene. A new empirical relationship for the permeation constant is evident from the results of the study.

In the last decade numerous papers have appeared on the subject of the permeation of gases and vapors, notably water vapor, through high polymeric films (*1*). Unfortunately the theory of permeation through solids (*2*) has not applied well to polymeric films (*1b*, *2*) therefore the need for data of a more systematic kind with concentration on a limited number of systems is indicated. Concurrent with the work of Simril and Hershberger we have in this laboratory acquired considerable data on the permeability of polymeric films to organic vapors by the cup method. Their papers obviate the necessity of publication of our results so we here limit our report to the vacuum permeation of a number of vapors through polyethylene. A new, empirical relationship for the permeation constant is evident. Incidentally, Amerongen (*3*) and Houwink (*4*) have given results on the diffusion of gases in caoutchouc and gutta-percha.

EXPERIMENTAL

The permeability of thin films of polyethylene to various organic vapors was measured using essentially the method described by Rouse (*5*) which involved some modifications of the earlier Barrer type of vacuum permeation apparatus. The temperature of the film chamber was kept at 25°C. and in some cases rates were also determined at 15°C. The permeation rate, G, was experimentally determined from a *time* vs. *increase in pressure* (δp) plot.* Subsequently, the permeability "constant," P, was calculated from the defining equation

$$P = \frac{lN}{At\,\Delta p} \qquad (1)$$

where P is the number of moles N passing through an area A (sq. cm.) in time t (sec.) at a vapor pressure differential, Δp, of 1 cm. Hg and through a film thickness l of 1 cm. The permeation rate G (mm. Hg per hr.) which could then be converted easily to N/t, was determined at various vapor pressures of the organic vapor.* The vapor pressures were controlled by the temperature of a dry-ice ethyleneglycol bath surrounding a reservoir of solvent, the pressure being read directly on a Hg manometer attached to the neck of the reservoir. The pressure could also be calculated from the vapor pressure-temperature curves of each solvent. Limitations were imposed on the maximum vapor pressure feasible (1) due to that of keeping the temperature of the reservoir below that of the permeation cell to prevent liquid condensation on the film and (2) due to the limited pressure difference which could be applied across the thin film before rupturing.

RESULTS

Tables I and II are compilations of the data so obtained including the calculated permeability constants, P. The apparatus was tested by comparing the data for water vapor ($P = 1.9 \times 10^{-13}$) with that published by Rouse (*5*) ($P = 2.0 \times 10^{-13}$) and was found satisfactory.

Previously published data (*1b*, *6*) on the permeability of various polymeric films to water vapor have shown that when the polymer film contains hydrophilic groups, the permeability constant is *not* independent of vapor pressure. This is a reasonable expectation since the equation for calculating P (*1*) was derived from Fick's law and from Henry's law of the solubility of gases (derivation in reference *2*). It is a well-known fact that the solubility of gases in polymeric films does not follow Henry's limiting law, i.e., the concentration of the vapor in the film is not a linear function of the vapor pressure (see any sorption isotherm (e.g., *1b*)). Instead, one finds that the solubility of the vapor is not a straight-lined function of vapor pressure. Therefore, if the concentration N is not directly proportional to vapor pressure it would not be expected that P be independent of the vapor pressure. We may conclude that the constancy vs. vapor pressure is valid only as a limiting case and if solution of the vapor is ideal, that is, no interaction between the vapor molecules and units of the polymer occurs. Figures 1 to 4 illustrate the dependency or variation of P with the vapor pressure of the organic solvent through a polyethylene film (0.0024 cm. thick). P is independent of vapor pressure for those solvents which do not dissolve in the hydrocarbon type film, and as water and acetone. However, the hydrocarbon type of solvents such as hexane, benzene, cyclohexane, etc., exhibit a definite dependency of P on vapor pressure. The chlorinated hydrocarbons, which would be expected to be compatible with the hydrocarbon chain, show the steepest variation of P with vapor pressure. It can be noted also, that in this limited region of study (up to vapor pressure of 2 cm. Hg) P seems to be a linear function of vapor pressure. Although this relationship may be due to the narrowness of the region investigated, in other cases this relationship pertains to the saturation vapor pressure at 25°. The theoretical implication of this effect is not known but is deserving of further study.

PERMEATION AND THE STRUCTURE OF THE PERMEATING VAPORS

Polythene is more permeable to the chlorinated hydrocarbons than to hydrocarbons. *Trans*-dichlorethylene is most permeable followed closely by 1,2-dichloroethane and *cis*-dichlorethylene. Their respective dipole mo-

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* *Note:* $(N/t) = (\delta pV/RTt) = G$, where V is the measured volume of the system in which the gas is measured at temperature T; R is the gas constant.

Table I. Vacuum Permeation Through Polyethylene (0.0024 Cm. Thick) 25°C.

Water, v.p., mm. Hg	G, *mm./hr.*	P, *moles cm./cm.². cm., Hg sec.*	*g./m². hr.*
		Propanol	
7.0	0.8	1.1×10^{-13}	0.07
11.0	1.2	1.1×10^{-13}	0.11
14.5	1.9	1.3×10^{-13}	0.17
19.0	2.9	1.5×10^{-13}	0.26
		Acetone	
6.2	0.3	0.47×10^{-13}	0.25
10.0	0.55	0.54×10^{-13}	0.047
14.0	0.9	0.63×10^{-13}	0.08
22.0	1.7	0.75×10^{-13}	0.15
25.3	2.1	0.81×10^{-13}	0.18
		Propionitrile	
4.5	0.4	0.9×10^{-13}	0.03
6.8	0.75	1.1×10^{-13}	0.061
11.2	1.5	1.3×10^{-13}	0.12
13.5	2.0	1.5×10^{-13}	0.16
18.7	3.0	1.6×10^{-13}	0.24
23.5	4.3	1.8×10^{-13}	0.35
		Benzene	
4.8	0.8	1.63×10^{-13}	0.09
10.0	2.45	2.4×10^{-13}	0.28
14.0	4.0	2.8×10^{-13}	0.46
16.0	5.2	3.2×10^{-13}	0.60
17.0	5.7	3.3×10^{-13}	0.65
19.5	...	3.7×10^{-13}	0.85
19.5	7.6	3.8×10^{-13}	...
21.0	10.1	4.7×10^{-13}	1.16
		Hexane	
6.0	0.2	0.33×10^{-13}	0.025
10.0	0.95	0.93×10^{-13}	0.12
14.0	1.5	1.05×10^{-13}	0.19
18.0	2.8	1.52×10^{-13}	0.35
23.0	4.15	1.76×10^{-13}	0.525
		Cyclohexane	
6.1	0.15	0.24×10^{-13}	0.019
15.0	1.7	1.1×10^{-13}	0.21
20.0	3.1	1.52×10^{-13}	0.38
23.1	4.1	1.74×10^{-13}	0.51
24.0	4.6	1.88×10^{-13}	0.57
		1,2-Dichloroethane (*sym*-ethylene chloride)	
7.7	2.2	2.8×10^{-13}	0.32
15.2	6.1	3.9×10^{-13}	0.89
21.2	11.8	5.45×10^{-13}	1.72
		trans-Dichloroethylene	
5.6	1.6	2.78×10^{-13}	0.23
9.2	3.45	3.66×10^{-13}	0.49
16.1	7.4	4.5×10^{-13}	1.05
19.3	9.7	4.9×10^{-13}	1.38
25.8	14.7	5.6×10^{-13}	2.10
		cis-Dichloroethylene	
6.4	1.85	2.82×10^{-13}	0.26
13.4	4.4	3.2×10^{-13}	0.63
12.7	4.0	3.05×10^{-13}	0.57
20.2	8.3	4.0×10^{-13}	1.18
22.8	10.6	4.55×10^{-13}	1.51
		Nitroethane	
4.5	1.0	2.2×10^{-13}	0.11
7.0	1.7	2.4×10^{-13}	0.19
8.8	2.0	2.3×10^{-13}	0.22
12.5	3.35	2.6×10^{-13}	0.37
19.5	6.35	3.2×10^{-13}	0.70

ments are 0, 1.12, and 1.8 Debye units indicating that the molecule with no dipole can permeate the nonpolar polythene film most rapidly (Table I).

The hydrocarbons hexane and benzene also have zero

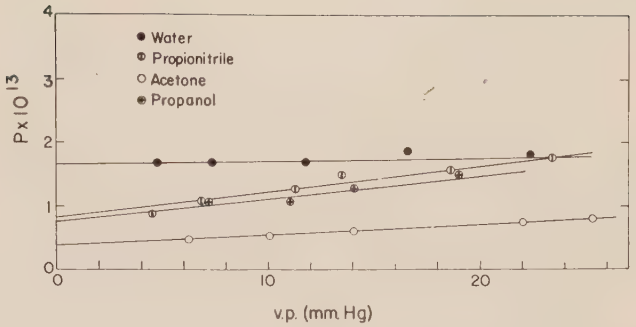

Fig. 1. Permeation of vapors through polyethylene at 25°C.

dipole moments. In this case, however, the structure of the molecule appears to control the permeating rate. Benzene, which has a coplanar structure, permeates faster than hexane which has a zig-zag chain structure. Cyclohexane, which is not coplanar, has the same permeating rate as hexane but not as benzene (a *planar* cyclic molecule).

The oxygen bearing compounds, as H_2O, acetone, propanol, all have much lower permeations (Table I). Propionitrile has a high dipole moment (4.0 debyes), and its permeation rate is low, about that of water.

SHAPE OF THE δp-TIME CURVE

The value of N/t (in equation for P) is determined

Table II. Permeation in Vacuum Through Polyethylene at 15.0°C.

Water, v.p., mm. Hg	G, *mm./hr.*	P, *moles cm./cm.² cm., Hg sec.*	*g./m². hr.*
		cis-Dichloroethylene	
6.2	1.1	1.73×10^{-13}	0.16
9.4	1.95	2.03×10^{-13}	0.28
12.2	2.9	2.3×10^{-13}	0.41
20.0	5.55	2.71×10^{-13}	0.79
22.9	7.5	3.2×10^{-13}	1.07
		1,2-Dichloroethane	
7.2	1.5	2.04×10^{-13}	0.22
15.2	4.5	2.9×10^{-13}	0.65
21.2	9.5	4.4×10^{-13}	1.39
		Hexane	
10.8	1.1	0.97×10^{-13}	0.13
18.0	2.9	1.57×10^{-13}	0.36
		Benzene	
6.7	1.4	2.0×10^{-13}	0.16
11.0	3.1	2.6×10^{-13}	0.35

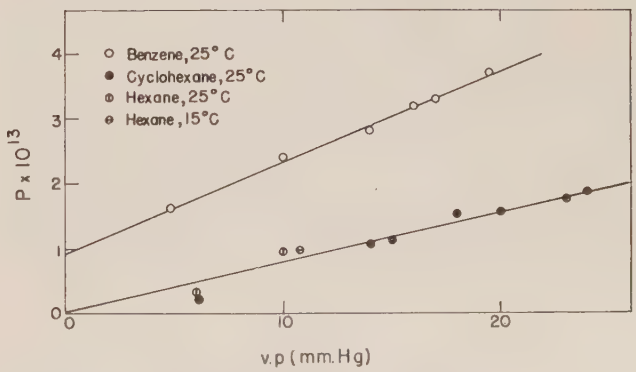

Fig. 2. Permeation of vapors through polyethylene

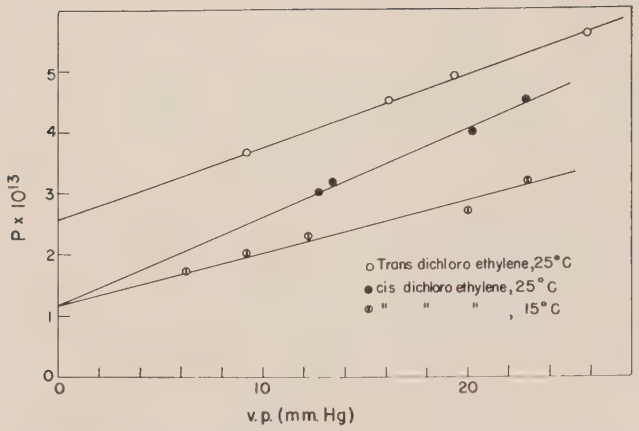

Fig. 3. Permeation of dichloroethylenes through polyethylene

from a pressure increase vs. time plot obtained experimentally in the Barrer vacuum permeation apparatus. In previously published results on the permeability of water vapor, this curve is characterized first by an induction period and then a linear curve from which the value of N/t can be calculated. However, in all the cases studied with the polyethylene film using the vacuum approach as modified by Rouse, no such induction period was noted. All the permeation-time curves issued from the origin with a constant slope (see Fig. 4).

The lack of an induction period may be due to: (1) a nearly zero solubility of water, propionitrile (ethyl cyanide) acetone, and the lower alcohols in the film at the vapor pressures used; or (2) in order to reduce low results, in the beginning we followed Rouse's suggestion to admit about 2 mm. of vapor to saturate the walls of the macrometer and the admission of the vapor may have saturated the film as well; or (3) both (1) and (2) may be involved.

ENERGY OF ACTIVATION

A few experiments at 15°C. in addition to those at 25°C. enabled us to calculate the energy of activation Ep necessary for the permeation process. The values are in Table III.†

The permeation process is made up of a diffusion process and a sorption process. Whether it is the simple

† One must be careful in comparing the results with E_P calculated from the cup method since the permeability constant varies with vapor pressure (see Figs. 2, 3) in the case of the hydrocarbons and chlorinated hydrocarbons through polyethylene. E_P should be calculated using the same vapor pressure of the solvent at the two temperatures; this we cannot do for the cup data. In the cases of water, acetone, alcohols, etc., it would be expected that for the Barrer and cup method, E_P's should compare favorably (P is constant).

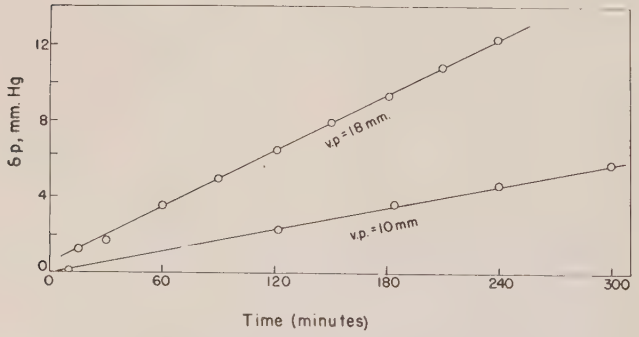

Fig. 4. Permeation of hexane through polyethylene (0.0024 cm. thick) at 25°C.

Table III. Energy of Activation of Permeation Through Polyethylene (0.0024 Cm. Thick) Between Temperatures of 15 and 25°C.

Vapor	*V.p., mm. Hg*	*E, kcal./mole*
1,2-Dichloroethane	7.2	3.6
	15.2	3.3
	21.2	2.4
cis-Dichloroethylene	13.4	3.3
	20.2	4.0
	22.8	3.8
Benzene	11	0
	6.7	0
Hexane	18	0
	10	0

relation $P = DS$, where D is the diffusion "constant" and S is the solubility coefficient (*2*) (as holds for several H_2O polymer systems) or whether it is a more complicated relationship depends upon the individual system. Rouse (*5*) has given a theoretical discussion of the nonconstancy of D in real systems. Nevertheless, we can describe P as being composed of a diffusion process and sorption.

Experimentally it has been shown that

$$P = P_0 e^{-E_p/RT}$$

Barrer (*2*) has shown that

$$E_p = E_D + E_s$$

under the ideal assumptions mentioned above where E_D and E_s are energies for diffusion and sorption.

The implication of the above relationship is that knowing E_p alone one does not have any insight as to the energies involved in both the diffusion and sorption. Hauser and McLaren found that E_p for H_2O through cellulose acetate was zero. E_s calculated from sorption studies was not zero but -12 kcal. per mole and therefore the energy of activation for diffusion was $+12$ kcal. per mole. This means that the diffusion constant required absorption of 12 kcal. of energy while the dissolving of the solvent gave off 12 kcal. The same argument can be applied to the permeation of benzene and hexane through polythene. These substances dissolve in the film to an appreciable extent and the slight heat of solution is counterbalanced by the energy of activation necessary for the diffusion of the solvent molecules.

If E_D and E_s continue to have equal and opposite values as the temperature changes then the value of P is known for all temperatures.

The results of these experiments emphasize the fact that the permeability constant as defined is not constant with respect to the pressure differential. Therefore, if one has determined permeabilities from cup measurements where the pressure of the solvent corresponds to that of the temperature of the cup, this permeation rate would probably differ from one determined at other partial or relative pressures. For this reason, our results differ from those published recently in a comprehensive study made by Simril and Hershberger. In essence, the permeation of benzene through polyethylene is roughly twice that of hexane but the absolute values are considerably different from those of Simril and Hershberger. To reiterate, in those cases where there is great compatibility between vapor and film, e.g., where a hydrocarbon type vapor permeates polyethylene or a hydrophilic vapor permeates polyvinyl alcohol one would expect extreme changes in P with vapor pres-

sure. These experiments are paralleled by nonlinear sorption isotherms. In addition, it has been found from these limited studies, that not only is P not constant but it appears to be a linear function of the vapor pressure of the permeating molecule.

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Color Removal of Process Waters

J. H. DAVIDSON

The Rainy River water has a high color, ranging from 40 to 80 p.p.m. which renders it unsuitable for use as a process water in the manufacture of bleached pulp and paper. This color is satisfactorily removed in the Minnesota and Ontario Paper Co.'s mill at International Falls, Minn., by coagulation with alum and lime in its 15,000,000 g.p.d. filtration plant which consists of two horizontal Permutit Precipitators and five gravity filters. About 2¼ g.p.g. of alum and 1½ g.p.g. of lime are employed plus, when required, from 1 to 2 g.p.g. of clay. Prechlorination with from 6 to 10 p.p.m. of chlorine is practiced which usually furnishes a sufficient residual in the effluent so that post-chlorination is only occasionally required. Costs for the chemicals used average somewhat less than 1½ cents per 1000 gallons. The filtered water is used in the new 200-ton-per-day bleach plant. Its purity, low color (2 to 4 p.p.m.), and lack of turbidity make it excellent for use in the production of high brightness pulps and papers. The filtration plant was put into service in September of 1948 and has been in continuous operation since that date.

Highly colored water supplies, with few exceptions, are surface waters which have originated in swampy areas. The color is derived from decaying vegetation, is organic in nature, and ranges from a light yellow to a rather dark brown. Generally, these waters are low in turbidity so that, aside from their color, most of them appear to be very clear. Also, these waters are usually low in hardness, alkalinity, and total mineral content. The depth of the color in a given supply varies over rather a wide range during the year so that it is quite common to find that the maximum color may be from 2 to over 5 times the minimum color.

These highly colored waters are unsuitable for use as process waters in the manufacture of bleached pulp and paper. Regarding this, TAPPI's monograph on "Industrial Water for Pulp, Paper, and Paperboard Manufacture" aptly states, "A water of little or no color is desirable for the manufacturing processes because highly colored waters adversely affect both white and dyed papers as well as pulps. Cellulose fibers readily absorb coloring substances and the stain may remain in the finished product."

TAPPI also offered, as a tentative specification, that the color tolerance should be 5 p.p.m. for higher grade products. It may be noted that a water having a color of only 5 p.p.m. appears colorless when viewed in a tumbler and that it is necessary to view it lengthwise in a Nessler tube in order to detect such a low color.

The Minnesota and Ontario Paper Co.'s Mill at International Falls, Minn., draws its water supply from the Rainy River. This water is a typical, highly colored surface supply, the minimum color being about 40 p.p.m. and the maximum color being about 80 p.p.m. with an average color of around 60 p.p.m. Table I shows the ranges in color and other constituents of the Rainy River water.

Table I. Rainy River. Ranges in Composition

Color, p.p.m.	40–80
Hardness as $CaCO_3$, p.p.m.	18–24
Alkalinity as $CaCO_3$, p.p.m.	16–26
Chlorides as $CaCO_3$, p.p.m.	1–2
Sulphates as $CaCO_3$, p.p.m.	3–7
Free carbon dioxide as CO_2, p.p.m.	2–10
Iron as Fe, p.p.m.	0.1–0.3
Turbidity, p.p.m.	0–15
pH	6.5–7.3

A series of tests were made to test the relative color removal efficacy of chlorination, activated carbon, and coagulation plus filtration. Chlorination did burn out some of the color but the degree of removal was woefully short of the goal for only about one third of

Fig. 1. Aerial view of International Falls—in foreground is community, while Minnesota and Ontario Paper Co. plant is shown across upper back section. Upper right shows International Bridge connecting International Falls and Fort Frances, Ont., Canada

J. H. Davidson, Chief Engineer, Minnesota and Ontario Paper Co., International Falls, Minn.

Fig. 2. The new, 200-ton-per-day bleachery at the Mando mill

the color was removed. A color of 60 p.p.m., for instance, was only reduced to about 40 p.p.m. and, as has been found with other highly colored waters, if the chlorine dosage to the breakpoint does not remove the color, additional amounts have little, if any, effect. Activated carbon also reduced the color only partially. However, the coagulation, settling, and filtration tests showed that a very satisfactory removal of the color could be effected by this method of treatment.

It was therefore decided to use this process in connection with our new 200-ton-per-day bleach plant and plans were accordingly drawn up for a 15,000,000 gallon per day water filtration plant to supply our own needs and also to furnish water for the city of International Falls. Figure 1 is a view of the Mando mill and part of the city of International Falls with the Rainy River in the background. Figure 2 is a view of our new, 200-ton-per-day bleachery, and Fig. 3 is a view of our new water filtration plant.

The raw water, pumped from the river, is delivered from the pumphouse to the filter plant through a 36-inch pipe line which discharges into a mixing flume. The raw water is prechlorinated as it enters the mixing

Fig. 3. Pure water for bleaching is assured as Mando's 15,000,000-gallon water filtration plant commences operation with the opening of the bleachery

flume, the dosages of chlorine ranging from about 6 to 10 p.p.m. Usually this affords a sufficient residual in the final effluent but, at times, postchlorination is also practiced, the dosage being about 0.5 p.p.m.

At a point further down the mixing flume, the alum, lime, and clay are added and mixed with the prechlorinated water. The dosages of chemicals used vary somewhat depending on the varying composition of the water but, in general, about $2^1/_4$ g.p.g. of aluminum sulphate and about $^1/_2$ g.p.g. of lime are employed. Dosages of clay range from 1 to 2 g.p.g. but may be entirely omitted when the flow required is not over 50% of capacity. The type and grade of clay found most satisfactory was The Proper Chemical Co.'s P-3 clay. Activated silica was also tried but was abandoned as it showed no advantages over the clay and had the disadvantage that it shortened the filter runs, these, on occasions, being only one half to one third as long as when clay was used.

From the mixing flume, the water enters the distributor flumes which introduce it into the upper part of the inner compartments of the two horizontal Permutit precipitators, each of which has a capacity of 7,500,-

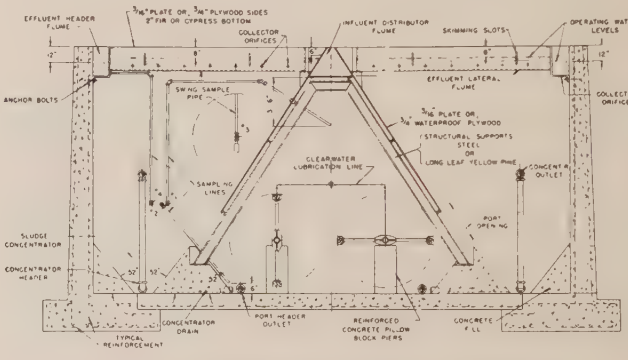

Fig. 4. Cross-sectional view of precipitator

000 g.p.d. These precipitators are 33 feet 6 inches wide by 112 feet long by 15 feet 4 inches deep, the shells being of concrete and the interiors being divided into inner and outer compartments by means of waterproof plywood partitions. As shown in Fig. 4, which is a cross-sectional view across the width of a horizontal precipitator, the partitions slope so that the inner compartments are narrowest at the top and widest at the bottom while the outer compartments are narrowest at the bottom and widest at the top.

Also, as shown, the inner compartment, through which the treated water flows downwardly, is equipped with two horizontally disposed, paddle-type agitators which are chain driven by an electric motor situated in a drive pit at one end of each precipitator. These agitators serve to mix thoroughly the treated water with previously formed precipitates and to form a large and quick settling floc. Emerging from ports in the lower part of the inner compartments, the flocculated water enters the outer compartments where its flow is reversed and it is filtered upwardly through a suspended blanket of previously formed sludge.

Due to the upwardly increasing cross-sectional areas of these outer compartments, the vertical upward velocity of the water steadily decreases in its passage through the outer compartments. This results in reaching a plane at which the upward flow of the water

is too slow to lift the sludge any further so that this plane marks the upper level of the suspended sludge blanket. It is remarkable how clear this plane of separation is; even when the temperature of the water is as low as 34°F., the top of the sludge blanket is sharply separated from the clear water rising above it to the outlet flumes. Figure 5 is a view taken at the top of the Precipitators showing the plywood inlet and outlet flumes and plywood effluent collector laterals.

In the coagulation and settling of high color waters in the older, conventional types of settling basin, the effluent, before filtration, usually has quite a marked color because of the tendency of some of the light floc to remain in suspension. But in the precipitators, due to the clarification effected by the upward filtration through the suspended sludge blanket, both the color and turbidity of the precipitator effluent, before filtration, are very low, often being only 8 p.p.m. in color and as little as 1.3 p.p.m. in turbidity. The height of the sludge blanket is kept within specified limits by electric time switches which are adjusted, as required, to regulate the length of blowdown periods so as to bleed off sludge from the sludge concentrators at the same rate as new sludge is being formed.

The effluent from the precipitators then passes to the gravity-type sand filters. There are five of these, each measuring 24 feet wide by 30 feet long by 13 feet deep. These are constructed of concrete with false bottoms fitted with noncorrodible porcelain strainers and, as shown in Fig. 6, the hydraulic valves are operated from manually operated control tables in the filter room.

The filters are operated at the high flow rate of 2.9 g.p.m. per square foot of bed area. Backwashing is performed at the rate of 15 g.p.m. per square foot of bed area and is assisted by the use of rotary surface washers which employ a flow of only $^3/_4$ g.p.m. per square foot.

The effluent from the filters discharges into a 789,000-gallon clearwell from which it is pumped to service in the mill. The city supply is drawn from the same clearwell but is handled by a separate pumping system and this city supply is treated with caustic soda, sodium silicate, and ammonium hydroxide.

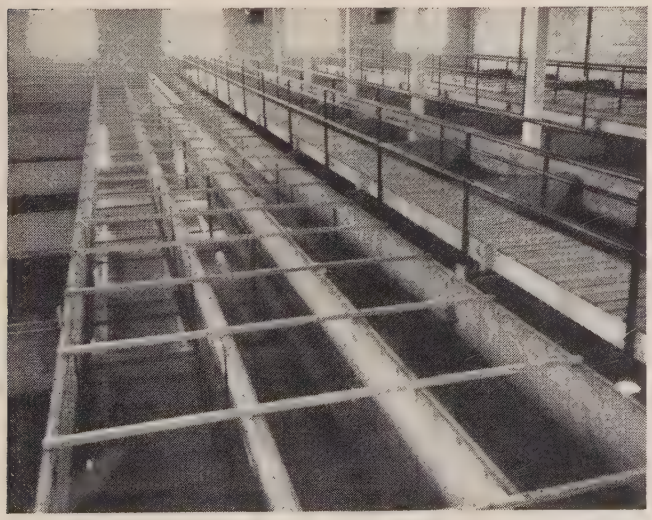

Fig. 5. View of the top of the precipitator showing inlet and outlet flumes

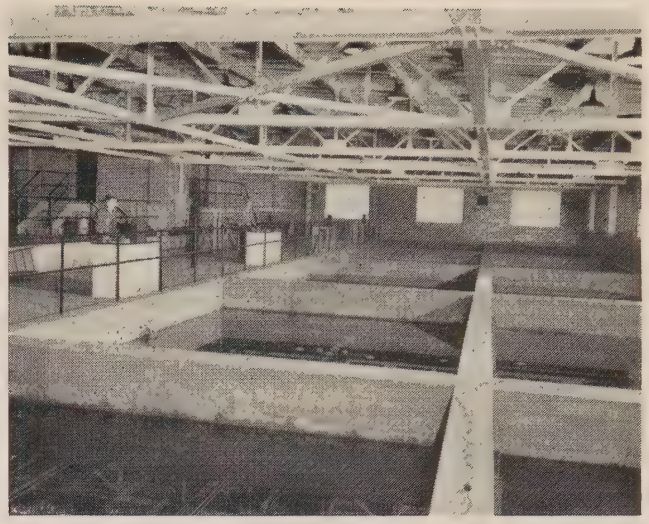

Fig. 6. One of the final steps in removing impurities from the water is the passage of the water through a series of filter beds

The new filtration plant was thrown into service in Sept., 1948, and has been in continuous operation since that date. No operating difficulties have been encountered and the color removal has been excellent, usually ranging from 2 to 4 p.p.m. residual in the filter effluent, which is well below the TAPPI tolerance of 5 p.p.m. Table II shows results with the raw water having a color of 55 p.p.m. and the filter effluents having a color of only 2 p.p.m. These data were obtained at flow rates of 50 to 75% of capacity, no data being available as yet at top flow rates.

Table II. Colors and Turbidities of Precipitator and Filter Effluents

	Color, p.p.m.	*Turbidity, p.p.m.*
1. Raw water	55	2.7
2. Effluent from precipitator no. 1	8	1.3
3. Effluent from precipitator no. 2	8	1.3
4. Effluent from filter no. 4	2	0.5
5. Effluent from filter no. 5	2	0.4

As production has increased in the bleach plant, the flow rate in the filtration plant has increased to the present rate of about 12,000,000 g.p.d. With the addition of groundwood bleaching facilities we expect that capacity flow will be approached. Continued good operation has been experienced at the higher flow rates and we anticipate no difficulties with capacity operation. Backwash water has amounted to about 3% of water treated and other water for utility uses about 1%.

The chemical costs to date have been somewhat less than was originally estimated and it is expected they will remain somewhat less than $1^1/_2$¢ per thousand gallons. Operation is, of course, more economical with respect to chemicals in the Summer due to the warmer water, the greater ease of flocculation, and more efficient settling.

The water from this treating plant has met all expectations. Its purity, low color, and lack of turbidity make it excellent for use in the production of high brightness pulps and papers.

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Effect of Melamine Resin on Chemical Tests of Paper

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A study of the effect of the presence of melamine-formaldehyde resin (MR) in paper on various chemical tests applied to paper is reported. Included are the determinations of alpha, beta, and gamma-cellulose, copper number, pH, rosin, cuprammonium fluidity, and the heat stability test. It was found that addition of MR generally increases the alpha-cellulose fraction, at the expense of the beta-portion. The alpha-cellulose fraction retains 70 to 85% of the MR. A decrease in copper number occurs; papers having a D.P. of 1000 or more are rendered only partially soluble in cuprammonium solvent; the analysis for rosin is unaffected. During hot water-extraction MR releases alkaline decomposition products; the hot-extraction pH of a paper therefore depends primarily on the relative amounts of alum and MR present. As measured by the changes occurring in alpha-cellulose and copper number on accelerated oven aging, MR exhibits a tendency to stabilize papers.

Considering the number of current uses for wet-strength paper, the variety of new products containing melamine resin-treated paper, and the amount of research currently devoted to this field, there can be no denying the present and coming importance of the melamine resins in their applications to paper. However, a search of the literature revealed little information concerning the effect of melamine-formaldehyde resin on the various chemical tests ordinarily applied to paper. For this reason a study of the effect of this resin on such tests was undertaken. The results are presented herein.

Methods of applying melamine resin to paper and the resulting effects on physical properties have been examined and carefully studied heretofore. Collins and Adrian (*1*) have provided an excellent review of the literature on wet-strength paper through 1947. Landes and Maxwell (*2*) present data showing the effect of melamine resin on the fold endurance test during oven aging, and discuss the difficulties involved in using this test as a criterion for the permanence of resin-treated papers. Maxwell and Reynolds (*3*) consider the effect of melamine resin on the permanence of papers and discuss briefly the effect of the resin on several chemical tests.

TESTS COVERED IN THIS STUDY

The following TAPPI Standard Methods were investigated in the course of this work:

T 408 m-46	Rosin in Paper and Paperboard
T 429 m-48	Alpha-, Beta-, and Gamma-Cellulose in Paper
T 430 m-47	Copper Number of Paper and Paperboard
T 435 m-42	Hydrogen Ion Concentration (pH) of Paper Extracts

In addition, the effect of melamine resin on the cuprammonium fluidity and on the determination of alpha-cellulose and copper number after accelerated oven aging was examined. The distribution of melamine resin between the alpha and beta plus gamma-cellulose fractions was also determined.

DESCRIPTION OF THE PAPERS TESTED

The papers used in this investigation, listed in Table I, were made in the National Bureau of Standards' semi-commercial mill under conditions simulating typical industrial practice, but much more carefully controlled and reproducible than is possible commercially.

Papers numbered 3, 5, 10, 13, and 14 were manufactured during a study of various types of experimental currency papers (*4*) and represent fine-quality papermaking fibers. Papers number 3 and 3M2 contain 50% linen and 50% cotton, whereas numbers 5 and 5M2 are 100% cotton. Number 10 and its companion 10M2 are 100% purified sulphate (hard alpha) fiber; 13 and 13M3 are made of 100% commercial sulphite pulp; 14 and 14M3 contain 100% purified sulphite (soft alpha). Symbols M2 and M3 refer to methods of adding the melamine resin colloid. The M2 papers and those without melamine contain no alum.

Papers 1452 through 1469 are lithographic offset-type papers which were made to determine the effects of resin bonding in the manufacture of such papers (*5*). The fiber content of these papers consists of 75% bleached Eastern sulphite and 25% bleached soda. Papers 1540 through 1593 are offset-type also; with the exception of 1591 and 1593, they were used in a further investigation of the application of resin bonding to the development of strength in offset papers (*6*). Numbers 1591 and 1593, containing 15% clay, were manufactured for a study of the effects of mineral filler on resin-bonded offset papers; the results of this study are as yet unpublished.

Papers 1540 and 1561 contain 50% bleached Eastern sulphite pulp and 50% bleached strong soda; 1568 and 1570 consist of 25% bleached Eastern sulphite and 75% bleached beech sulphate; papers 1562, 1564, 1591, and 1593 contain 25% bleached Eastern sulphite and the remainder bleached strong soda.

The specific melamine resin (hereinafter designated as MR) used in these papers and throughout this work was Parez No. 607 (American Cyanamid Co.). The resin colloid solutions were prepared according to the method recommended by the manufacturer*: the dry resin was dissolved in sufficient dilute hydrochloric acid at 140°F. to yield a resin-solids concentration of 20% and a mole ratio, resin to acid, of about 1 to 0.8; this solution was then diluted with cold water to produce a resin concentration of 12% at 90 to 95°F. The resin solution was allowed to age at least 12 hours before use. For further information on the papers, method of manu-

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* The manufacturer now recommends a different procedure.

Table I. Effect of Melamine Resin on Chemical Tests

Paper no.	Beating time, hr.	Rosin content,[a] %	Melamine resin[b] Furnished,[a] %	Melamine resin[b] In paper,[a] %	Fraction in alpha-cellulose, %	Cellulose fractions[c] Alpha,[d] %	Beta,[d] %	Gamma,[d] %	Copper no.	Cuprammonium D.P.	Fluidity rhes
1452	1 1/2	0.8	0.0	0.0	..	81.6	8.9	9.5	1.7	685	24.0
1467	1 1/2	0.7	0.5	0.37	..	82.3	8.6	9.1	1.6	705	23.4
1466	1 1/2	0.7	1.0	0.94	81	82.5	8.0	9.5	1.6	710	23.3
1463	1 1/2	0.6	2.0	1.52	74	83.4	7.3	9.3	1.4	760	21.6
1453	1 1/2	0.7	3.0	1.70	..	84.0	6.6	9.4	1.3	700	23.6
1455	5 1/2	0.8	0	0	..	81.5	10.0	8.5	1.9	675	24.3
1469	5 1/2	0.9	0.5	0.47	..	82.7	8.2	9.1	1.7	695	23.8
1468	5 1/2	0.9	1.0	0.81	75	82.6	8.5	8.9	1.6	665	24.8
1464	5 1/2	0.7	2.0	1.55	75, 72	82.6	7.5	9.9	1.5	735	22.4
1456	5 1/2	0.8	3.0	2.30	..	83.6	7.4	9.0	1.6	720	22.9
1458	9 1/2	0.8	0	0	..	80.3	10.5	9.2	1.9	735	22.3
1459	9 1/2	0.8	3.0	2.51	..	83.4	7.1	9.5	1.5	750	22.0
1540	..	1.2	0	0	..	81.6	11.6	6.8	1.6	735	22.3
1561	..	1.1	3.0	2.12	..	84.2	8.8	7.0	1.2	785	20.9
1562	..	1.2	0	0	..	80.0	14.9	5.1	1.7	560	29.0
1564	..	1.0	3.0	2.55	85	83.1	12.1	4.8	1.2	580	28.2
1568	..	0.8	0	0	..	80.5	14.8	4.7	1.7	625	26.4
1570	..	0.8	3.0	2.28	..	83.1	11.9	5.0	1.2	595	27.4
1591	..	1.2	0	0	..	80.6	14.1	5.3	1.7	595	27.4
1593	..	1.1	3.0	2.12	..	82.9	11.7	5.4	1.4	615	26.6
3	..	[e]	0	0	..	94.4	3.8	1.8	0.6	1420	9.24
3M2	..	[e]	3.0	2.70	..	94.3	4.8	1.0	0.4	Ins.[f]	Ins.
5	..	0	0	0	..	95.2	4.3	0.5	0.3	1440	9.06
5M2	..	0.2	3.0	2.54	85	94.5	4.7	0.8	0.2	Ins.	Ins.
10	..	[e]	0	0	..	88.3	3.8	7.9	..	1170	12.6
10M2	..	[e]	3.0	2.99	..	89.8	2.6	7.6	..	Ins.	Ins.
13	..	[e]	0	0	..	84.0	3.7	11.1	..	1040	15.0
13M3	..	[e]	3.0	2.57	..	85.2	2.8	12.0	..	Ins.	Ins.
14	..	[e]	0	0	..	91.1	..	..	0.8	1120	13.6
14M3	..	[e]	3.0	2.69	85	92.3	..	..	0.6	Ins.	Ins.

[a] Per cent of moisture-free paper.
[b] Based on nitrogen determination. Factor of 2.62 used.
[c] MR fraction in alpha-portion assumed to be 80% if not known.
[d] Per cent of total MR-free and rosin-free cellulose.
[e] No rosin size added; natural resins not determined.
[f] Paper incompletely soluble.

facture, or papermaking equipment used, the reader is referred to the original articles.

VOLUMETRIC ALPHA-CELLULOSE TEST

Consideration of the effect of melamine resin on the volumetric alpha-cellulose determination discloses two possibilities: the effect of resin bonding in increasing the amount of cellulosic material insoluble in sodium hydroxide, and the necessity of correcting for the consumption of dichromate by the melamine. The latter requires a knowledge of the dichromate equivalent of the resin, as well as a knowledge of its distribution among the cellulose fractions. Knowledge of the distribution of the resin is required for the gravimetric method also, in order that correction may be made for the weight of resin retained in the alpha-cellulose portion.

It might be well to point out that any increase in the alpha-cellulose fraction resulting from resinbonding would not be an increase in alpha-cellulose content in the pure academic sense, wherein alpha-cellulose is defined as consisting of only the alkali-resistant long chains made up solely of beta, D-glucopyranose units.

In the discussion that follows, the term alpha-cellulose is used to indicate an analytical value, i.e., the fraction of the total cellulose, irrespective of its composition, that is insoluble in sodium hydroxide solution under the conditions described in the standard method.

Dichromate Equivalent of Melamine Resin

The melamine resin content of a paper is customarily calculated in terms of the monomer (trimethylol form), based on the nitrogen analysis. Therefore the dichromate equivalent of the monomer was used in computing the correction for consumption of dichromate by MR. No error is introduced by such procedure provided the condensation of the resin occurs by the release of water. The release of an oxidizable by-product, as, for example, formaldehyde, is of course not accounted for.

In evaluating the dichromate equivalent of the resin the general method outlined by Launer (7) was followed. A solution of MR in dilute HCl, containing 2 grams of the as-received resin per 500 ml. was prepared. Five-milliliter portions of this solution were pipetted into 400-ml. beakers containing 5 ml. of 1.835 *N* potassium dichromate, 50 ml. concentrated sulphuric acid, and 45 ml. distilled water. These solutions were held at 140 to 150°C. for 2 to 10 minutes, cooled, and titrated with ferrous ammonium sulphate. Results are given in Table II.

Table II. Dichromate Equivalent of MR

Oxidation time, min.	$K_2Cr_2O_7$ equivalent, g. dry MR per ml. 1.835 N $K_2Cr_2O_7$[a]
2	0.0135
4	0.0131
8	0.0133
10	0.0135
Av.	0.0133

[a] 3% moisture assumed in resin as received.

It is interesting to note that complete oxidation of the resin occurs in less than 2 minutes. Assuming that the reaction proceeds in the following manner:

$$C_6H_{12}O_3N_6 + 5K_2Cr_2O_7 + 20H_2SO_4 \rightarrow 6CO_2 + 3N_2 + 5K_2SO_4 + 5Cr_2(SO_4)_3 + 26H_2O$$

the value obtained agrees very well with the theoretical

dichromate equivalent of 0.0132 gram MR per ml. of 1.835 *N* dichromate.

Distribution of MR Between the Alpha and Beta Plus Gamma-Cellulose Portions

In determining the distribution of MR between the alpha and beta plus gamma-fractions, six disintegrated specimens of customary size (0.300 gram) were carried through the filtration step in accordance with TAPPI Standard T 429 m-48, at which point the alpha pads were combined to form duplicates for nitrogen analysis. TAPPI Standard T 418 m-45, with slight modification, was used throughout this study for the determination of nitrogen.

Results on seven papers are shown in column six of Table I. No trends are apparent in the data, but this is not unexpected, considering the many factors that affect the retention of melamine resin, and probably the distribution in the paper as well. Furthermore, the error involved in any one determination of the fraction of MR retained by the alpha-cellulose portion is rather large. Assuming a possible error of ±0.01% nitrogen, the maximum error of a single determination is of the order of ±3%. Duplicates on paper 1464 are within this error.

Effect of the MR Correction on the Calculation of Alpha-Cellulose Content

In calculating the alpha-cellulose value as per cent of total cellulose, the effect of applying the correction for consumption of dichromate by the melamine resin in a paper can be illustrated by considering the normal range of alpha-cellulose, the possible range of the fraction of MR retained by the alpha-cellulose portion, and comparing the alpha-cellulose values obtained after applying the MR correction with the uncorrected values. This has been done for the amounts of MR usually found in wet-strength papers; results are tabulated in Table III.

Table III. Effect of the MR Correction on the Alpha-Cellulose Value

Nitrogen content of paper, %	*Equivalent MR content,*[a] %	*Alpha-cellulose value, uncorrected,* %	*Alpha-cellulose value,*[b] *corrected for MR, % Fraction of MR in alpha-portion* 0.70	0.85
0.30	0.79	70.0	70.0	69.9
0.60	1.57		70.0	69.7
0.90	2.36		70.0	69.6
1.20	3.14		70.0	69.5
0.30	0.79	80.0	80.1	80.0
0.60	1.57		80.2	79.9
0.90	2.36		80.3	79.9
1.20	3.14		80.3	79.8
0.30	0.79	90.0	90.2	90.0
0.60	1.57		90.4	90.1
0.90	2.36		90.6	90.1
1.20	3.14		90.6	90.2
0.30	0.79	95.0	95.2	95.1
0.60	1.57		95.4	95.2
0.90	2.36		95.7	95.3
1.20	3.14		95.7	95.3

[a] Factor of 2.62 used.
[b] Per cent of total cellulose, MR-free and rosin-free.

It can be seen that even in more exact work corrections for the quantities of MR usually present in papers need not be applied in obtaining the distribution of the total cellulose in a sample among the three fractions, since the resulting changes in the alpha and beta-cellulose values are of the order of reproducibility of the method. The correction for consumption of dichromate by the MR must, of course, be made on converting to a basis of per cent of dry sample weight.

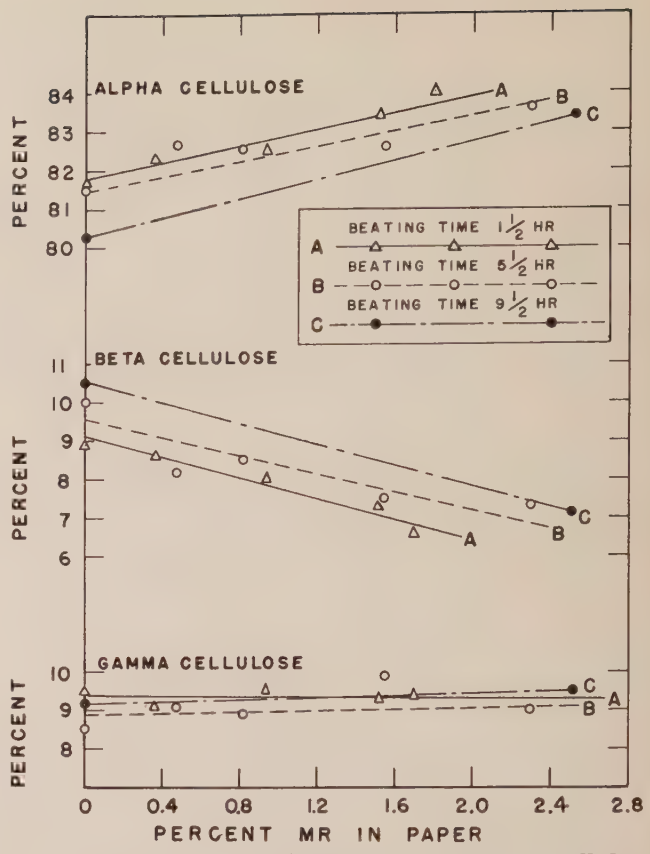

Fig. 1. Effect of MR on alpha, beta, and gamma-cellulose content

Effect of MR on the Alpha-Cellulose Value

The addition of melamine formaldehyde resin to a paper stock usually increases the alpha-cellulose value of the paper. The amount of the increase depends on the initial alpha-cellulose content and on the amount of resin added. Figure 1 is a graphic representation of the data in Table I on lithographic offset papers 1452 through 1469, containing 75% bleached sulphite and 25% bleached soda. The data in Table IV, also taken from Table I, on papers to which 3% MR was added, show that the effect of melamine resin on the alpha-cellulose value seems to be more closely related to the initial alpha-cellulose content than to the source and treatment of the fibers. The alpha-cellulose content of the 100% cotton paper containing 3% MR is 0.7% less than the same paper without MR. It is not known whether this decrease is significant.

That the effect of the resin in increasing the alpha-cellulose value should become less pronounced with increasing initial alpha-cellulose is expected since there are progressively fewer short chains to be bound.

Effect of MR on the Gamma-Cellulose Fraction

No attempt was made to determine the distribution of the remaining melamine resin between the beta and gamma-cellulose portions, and no MR correction was subtracted from the gamma dichromate figure in computing the gamma-fractions recorded in Table I. However, for the papers studied the dichromate equivalent

of the melamine resin not retained in the alpha-cellulose portion amounts to only 0.04 to 0.13 ml. If one considered this entire amount to be in the gamma portion, a possibility that seems highly unlikely, the gamma values would be lowered by an average of less than 0.5% cellulose. Even with these maximum corrections applied, the gamma-cellulose values of the papers with and without melamine resin would agree within the limits of experimental error (±0.6% cellulose for the average of duplicates). Therefore it may be concluded that the increase in alpha-cellulose resulting from the addition of MR is primarily due to binding of the intermediate-length cellulose chains normally entering the beta-fraction, and that the MR has no similar effect on the short chains of the gamma-fraction (see Fig. 1).

DETERMINATION OF COPPER NUMBER

The data (column 10, Table I) show quite definitely that the addition of melamine resin in manufacture produces a decrease in the copper number of a paper. As with alpha-cellulose content, the change is dependent on the amount of MR added and on the initial copper number; a given quantity of resin produces a larger change on papers having a high initial copper number. Figure 2 shows the effect of MR on copper number, fluidity, and rosin content of papers 1452 through 1469.

A more sensitive method for the detection of aldehyde groups in cellulose, using sodium chlorite, is being developed. It is hoped that this method will enable the relationship between melamine resin and aldehyde groups in cellulose to be studied more closely.

CUPRAMMONIUM FLUIDITY

The cuprammonium fluidity of the papers was determined using the procedure of Launer and Wilson (*8*); the results, expressed in rhes and as degree of polymerization (D.P.), are listed in Table I. The D.P. values were calculated according to the method of Battista (*9*). In papers of low D.P. (550–750) the addition of up to 3% MR has only a slight effect in decreasing the cuprammonium fluidity (see Fig. 2). At higher D.P. (above 1000), the addition of 3% melamine resin renders a paper only partially soluble in cuprammonium solvent at 0.5% concentration; fluidity measurements therefore become meaningless. This confirms the experience of Maxwell and Reynolds (*3*) in measuring the cupriethylene diamine fluidities of papers with and without MR.

pH OF PAPER EXTRACTS

Launer (*10*) has shown that papers containing papermaker's alum (but without melamine resin) yield a hot-extraction pH 0.6 unit lower, on the average, than the cold extraction pH due to irreversible hydrolysis of the alum on heating.

Table V. pH of Papers Containing MR and Alum

MR in paper, %	*pH*		*Difference (hot minus cold)*
	Cold	*Hot*	
0.78	5.6	5.2	−0.4
0.91	5.3	5.0	−0.3
0.96	5.0	4.8	−0.2
1.04	5.8	5.3	−0.5
1.14	5.3	5.1	−0.2
1.72	4.7	4.9	+0.2
2.05	4.8	4.7	−0.1
2.11	4.6	4.6	0.0
2.18	5.2	5.2	0.0
2.21	5.3	5.0	−0.3
2.24	4.8	4.9	+0.1
2.26	4.7	4.9	+0.2
2.29	4.7	5.0	+0.3
2.37	4.9	4.8	−0.1
2.55	5.0	5.0	0.0
2.78	4.9	4.9	0.0
3.14	5.0	5.0	0.0

Table V presents a representative portion of data accumulated on papers containing varying amounts of alum and melamine resin. These data show that the presence of MR in increasing quantity progressively reduces the difference between the cold and hot-extraction pH's, and may even render the hot-extractions pH higher. It has been found that suspensions of MR in water, heated on a steam bath for 1 hour, show a rise in pH. The following results were obtained on solutions containing MR in amounts similar to those present in the determination of the pH of an MR-treated paper:

MR in 50 ml. distilled water, mg.	*pH, cold-extract*	*pH, hot-extract*
15	6.27	7.38
30	6.44	7.70

It is obvious then that during hot-extraction of a paper containing both alum and melamine resin two conflicting hydrolyses are occurring, one resulting in acid products, the other in alkaline, with the final pH depending primarily on the relative amounts of alum and melamine resin present.

DETERMINATION OF ROSIN

One per cent of rosin size was added in the beater to all except the currency papers, and precipitated with alum prior to addition of the MR colloid. Examination of the data (Table I) discloses that the presence of MR

Table IV. Variation of Increase in Alpha-Cellulose with Initial Alpha-Cellulose Value

Papers	*Fiber content*	*Alpha-cellulose sheet without MR, %*	*Alpha-cellulose,[a] sheet with 3% MR, %*	*Increase[a] in alpha-cellulose due to 3% MR, %*
1562, 1564	25% sulphite, 75% soda	80.0	83.1	3.1
1458, 1459	75% sulphite, 25% soda	80.3	83.4	3.1
1568, 1570	25% sulphite, 75% beech sulphate	80.5	83.1	2.6
1591, 1593	25% sulphite, 75% soda	80.6	82.9	2.3
1455, 1456	75% sulphite, 25% soda	81.5	83.6	2.1
1540, 1561	50% sulphite, 50% soda	81.6	84.2	2.6
1452, 1453	75% sulphite, 25% soda	81.6	84.0	2.4
13, 13M3	100% sulphite	84.0	85.2	1.2
10, 10M2	100% purified sulphate	88.3	89.8	1.5
14, 14M3	100% purified sulphite	91.1	92.3	1.2
3, 3M2	50% linen, 50% cotton	94.4	94.3	−0.1
5, 5M2	100% cotton	95.2	94.5	−0.7

[a] Per cent of total MR-free and rosin-free cellulose.

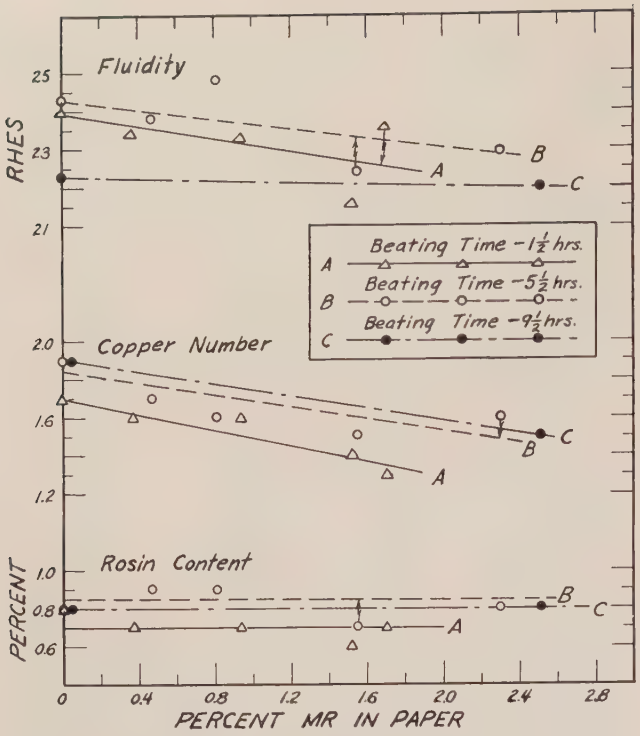

Fig. 2. Effect of MR on copper number, fluidity, and rosin content

in a paper does not change the quantity of rosin found by TAPPI Standard T 408 m-46 (see Fig. 2). We may also conclude that with addition of rosin size and MR in the above manner, retention of rosin size is not affected.

ACCELERATED AGING

The presence of synthetic resin in a paper introduces at least one additional variable that at present precludes normal interpretation of the heat stability test (T 453 m-41), namely the variation in the cure of the resin. Landes and Maxwell (*2*) show that the fold endurance of MR-treated papers may greatly exceed the original value during the early stages of the heat stability test, owing to additional curing of the resin, and that the final fold endurance may often be higher than the original value. This shows that variations in the cure of the resin prior to and during oven aging can have a profound effect on the fold endurance and on fold endurance retention.

Inasmuch as the papers used in this investigation were 2 or more years old, it was expected that the melamine resin would be fully cured, especially in those papers of lower pH. Fold endurance tests of several papers at the 8 and 16-hour intervals of oven aging indicated that such was the case; no rise in fold endurance was found, but rather a steady decline from the initial value, even on paper 3M2, to which no alum was added in manufacture.

In addition to the determination of fold endurance retention, changes in alpha-cellulose and copper number on oven aging can be used as measures of the relative permanence or stability of papers. These tests are not as satisfactory as the fold endurance since the changes occurring in alpha-cellulose and copper number on oven aging are smaller and not as closely related to the strength properties of the sheet. However, it has been found (*11*, *12*) that, in general, the more unstable papers, as measured by loss in fold endurance, also experience appreciable decreases in alpha-cellulose content and increases in copper number.

Table VI summarizes the results of tests on papers aged in a circulating-air oven at 105 ± 2°C. The 8, 16, and 32-hour alpha-cellulose values are single determinations; the 0 and 72-hour values and all copper numbers are the averages of duplicate tests.

Shaw and O'Leary (*13*) have demonstrated that acidity is of primary importance in the deterioration of paper, the degradation on heating or natural aging becoming more severe as the pH of the paper decreases. The pH of each MR paper listed in Table VI is in every case significantly lower than the corresponding MR-free paper. Consideration of these facts and of the data in Table VI leads to the conclusion that melamine resin exhibits a tendency to stabilize papers.

The pH's of papers containing MR need not necessarily be lower. Landes and Maxwell (*2*) have shown that good resin retention and wet-strength development can be realized even in almost neutral papers.

SUMMARY

Melamine resin in paper distributes itself between the alpha and beta plus gamma-cellulose fractions in approximately the ratio of the two fractions, so that the correction for consumption of dichromate by the resin in the volumetric alpha-cellulose test has usually a negligible effect. Incorporation of melamine resin into a paper ordinarily increases the alpha-cellulose fraction through resin bonding; the increase ranges from 0 to 3% cellulose (as per cent of total cellulose) for the amounts of melamine resin normally added, and depends on the original alpha-cellulose content of the fibers as well as on the amount of resin present. The increase occurs at the expense of the beta-cellulose fraction since the amount of gamma-fraction is not changed.

Melamine resin produces a decrease (0.2 to 0.4) in the copper number of a paper; papers having an original D.P. of 1000 or more are rendered partially insoluble in cuprammonium solvent at 0.5% concentration, so that

Table VI. Accelerated Aging of Papers Containing MR

Paper	Cold pH	% MR	% Alpha-cellulose — Aging time at 105°C., hr. 0	8	16	32	72	Change after 72 hr.	Copper no. — Aging time at 105°C., hr. 0	8	16	32	72	Change after 72 hr.
1562	5.3	0	80.0	80.6	79.5	78.2	77.2	−2.8	1.7	1.9	2.0	2.1	2.2	+0.5
1564	4.8	3.0	83.1	82.2	81.7	81.5	80.3	−2.8	1.2	1.4	1.5	1.5	1.6	+0.4
3	6.2	0	94.4	94.6	92.1	94.1	92.6	−1.8	0.6	0.9	0.5	0.8	0.7	+0.1
3M2	5.6	3.0	94.2	94.8	94.9	94.0	93.9	−0.3	0.4	0.4	0.5	0.5	0.5	+0.1
1455	5.7	0	81.5	..	..	..	79.0	−2.5	1.9	..	..	..	2.4	+0.5
1456	4.7	3.0	83.6	..	..	..	82.5	−1.1	1.6	..	..	..	1.7	+0.1
14	6.3	0	91.1	..	..	..	90.9	−0.2	0.8	..	..	..	1.0	+0.2
14M3	5.2	3.0	92.3	..	..	..	91.9	−0.4	0.6	..	..	..	0.6	0.0

viscosity measurements become meaningless; the analysis for rosin is not affected.

During hot water-extraction melamine resin hydrolyzes, releasing alkaline products; as a consequence, the hot-extraction pH of a paper containing both alum and melamine resin may be higher, lower, or equal to the cold pH, depending on the relative amounts of alum and resin present.

Indications are that melamine resin tends to stabilize papers, as measured by the changes occurring in alpha-cellulose and copper number on accelerated oven aging. Whether this stabilization is related to the resistance of the paper to deterioration on natural aging remains to be determined. Much work must be done before the heat stability test can be considered a satisfactory measure of the relative permanence of papers containing synthetic resins.

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Drying 800 Tons Kraft Board Daily on One Machine

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The drying of a quantity in excess of 800 tons per 24 hours of kraft board on one machine entails the handling of quantities of stock, steam, water, air, and supplying of power which are rather unusual to the industry. This paper, then, is a description of the equipment, along with the quantities of the above materials and services used in producing such results, a calculation of drying and evaporation rates, and comparison of these rates with earlier published figures.

In the central part of Georgia there started on April 30, 1948, the actual operation of the Macon Kraft Co., producers of linerboard. As is probably usual in new mills, various and sundry problems arose, but one by one these were overcome and production rates continued to move forward, until on April 15, 1950, a record run of 838.99 net, gross 867.36, tons of board was produced. This record-producing day had been preceded by two days of 790 and 813 tons, respectively.

The production of this quantity of board stands not only as a tribute to the outstanding management of the mill, but also to the loyalty and efforts of the operating personnel without whose accomplishments a job of this magnitude would have been impossible.

The drying of board in large quantities, which we are now primarily interested in considering, consists basically in the removal of water. Removal of water in present operations is handled in three distinct categories on the paper machine. First is the water removed by natural drainage from the web through the wire; second is the water removed by the application of vacuum at the flat boxes, couches, and suction press rolls, which might be termed forced drainage by mechanical means; and third the removal of water by evaporation as a result of the application of heat at the driers.

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EQUIPMENT

In order to gain some idea of the magnitude of the equipment required in an operation of this size an attempt will be made to describe the major items.

The headbox is of the conventional open pond-type with a square slice, furnished stock and water by a 28,000-g.p.m. fan pump which draws its water supply from the wire pit.

The fourdrinier, which is slightly over 58 feet long from breast roll to couch, uses a 216-inch wire by 130 feet long. Ten flat boxes for initial water removal are followed by a 40-inch primary couch at the point where the wire breaks down to the main couch which is also 40 inches in diameter. A wire dandy is employed between the sixth and seventh flat boxes, and a rubber-covered lump breaker roll at the main couch.

Following the fourdrinier are two dual press sections, the first press containing two rubber-covered suction rolls, the second press having one suction roll and one smoothing role.

Vacuum for the flat boxes is supplied by a rotary vacuum pump rated 2230 c.f.m. at 10 inches Hg. Vacuum for the primary couch was supplied by two rotary vacuum pumps rated 2120 c.f.m. at 20 inches Hg each; main couch pumps consisted of one pump rated 2120 c.f.m. and two rated 1980 c.f.m. each, all at 20 inches Hg. The first suction roll in the first dual press used two pumps rated 1980 c.f.m. at 20 inches Hg each, the second suction roll, first press, and the suction press roll in the second dual each were connected to a rotary pump rated 1980 c.f.m. at 20 inches Hg. The total in-

stalled capacity at the time of this record run was 18,080 c.f.m. at 20 inches Hg and 2230 c.f.m. at 10 inch Hg. Drives for these pumps consisted of five 250-hp. synchronous, double-extended shaft motors, two pumps being driven by one motor.

Directly following the smoothing roll of the second dual press are the driers, the largest part of the machine, which stretch for a distance of 332 feet-9 inches from the center of the first drier to center of last drier. The drier section is the typical two-deck arrangement with the driers broken down into six sections, separated between the third and fourth sections to accommodate a breaker stack. The drier section consists of 102 paper driers, and 22 felt driers. The first section consists of 18 paper driers, with three each top and bottom felt driers, two each top and bottom being Feeney driers. The second drier section contains 18 paper driers, six felt driers, three each on the top and bottom felts, two on each felt being used as Feeney driers. Third section driers consist of 18 paper driers, and two each top and bottom felt driers, one on each felt being a Feeney drier. The fourth, fifth, and sixth sections have 16 paper driers each, with two felt driers to each section, one each on top and bottom felts. During the period of this run no felt was being used on the sixth bottom position. Following the drier section we have a double calender with three calender driers between stacks.

All driers are of cast iron construction, 60 inches in diameter, with a shell face of $215^{3}/_{4}$ inches (17 feet $11^{3}/_{4}$ inches) total face width of drier being 218 inches (18 feet 2 inches). Driers are designed for 125-pound operating steam pressure and balanced for operation at 1500 f.p.m. paper speed. Condensate and air removal from the driers proper is by means of a rotating siphon with universal balanced steam fit furnished by the machine builder.

STEAM SUPPLY AND CONDENSATE REMOVAL

Steam at the mill is generated at 900 p.s.i. and 825°F. with main header pressure of approximately 850 p.s.i. and 825°F. Process steam at 150 p.s.i. is from extraction on two of the turbogenerators, exhaust from the 2000-hp. turbine which drives the machine lineshaft, and any deficiency from these points is made up directly from the 850-p.s.i. header through a reducing station in the power plant. One hundred and fifty pounds per square inch steam is passed through desuperheaters to bring the temperature to a point just above saturated at this pressure.

The drier section is provided with two forced vapor circulating systems with one common condensate condenser.

A sectional supply header with three divisions is provided for the wet end system, steam from the main 150-pound main supply being admitted to the section supplying the 41 driers beginning at no. 14 from the wet end and ending at drier no. 54 at the breaker stack, as well as the 16 felt driers in the wet end drier section. The second section of the supply header, utilizing flash and recirculated steam from the 42-inch main steam separator at the wet end which acts as collector for condensate from the 16 felt driers and 41 paper driers as noted above, supplies nine paper driers, nos. 5 through 13 inclusive. The third section header, utilizing flash and recirculated steam from the 30-inch flash steam separator which serves as a collector for the condensate returns from driers 5 through 13 inclusive, supplies driers 1 through 4 inclusive at the wet end. These four driers are provided with condensate and air separating traps for controlling and discharging the condensate and air which is returned to a 30-inch low-pressure steam separator common to both drier sections.

The dry end section, starting at the first drier beyond the breaker stack and ending just ahead of the first calender, includes driers 55 through 102 inclusive and six felt driers. A sectional header for the dry end section is similar to that in the wet end section, steam being supplied from the 150-pound main header to the first sectional header which supplies steam to driers 68 through 102 inclusive and the six felt driers. Steam supply for the second sectional header, which supplies driers 59 through 67 inclusive, is provided from flash and recirculated steam at the main 36-inch dry end separator acting as a collector of condensate returns from driers 68 through 102 and six felt driers. The third sectional header which supplies steam to driers 55 through 58 inclusive gets its supply as flash and recirculated steam from the 30-inch dry end flash separator which acts as a collector of condensate return three from driers 59 through 67 inclusive. These driers are also supplied with condensate and air separating traps which discharge air and condensate to the condensate cooler and thence to the common low-pressure steam separator.

The sectional headers above are connected by pressure differential regulating valves for controlling the pressure differential between sections of the header to supplement the amount of steam flashed and recirculated from the steam separators to the low-pressure section. This differential is maintained at approximately 5 pounds.

The three calender driers have an independent system supplied from the 150-pound steam supply and are provided with condensate and air separating traps which discharge through the condensate coolers to the low-pressure steam separator.

A four-pass, counterflow heat exchanger cools condensate from driers 1 through 4, 55 through 58, three calender driers and return from air heating coils, below 212°F. or atmospheric pressure and returns it to a 30-inch low-pressure separator where air or noncondensable gases are collected and discharged to atmosphere.

A control panel for the forced circulating vapor system is located at the dry end of the paper machine to allow changes being made in pressure to the driers by the backtender who is nearest the testing station and aware of any radical changes in moisture content of the sheet at the reel. The panel provides mountings for gages which read main header pressure, calender supply header, wet end supply header, and dry end supply header pressures. This panel also contains recorders for total steam to driers, wet end supply header, dry end supply header, and calender supply header pressures.

Condensate from all separators is returned to the powerhouse for reuse as boiler feedwater and provides no small part in the 30% make-up figure for the plant.

On Fig. 1 is shown the arrangement of all driers, and the arrangement of sectional headers is apparent from the header pressures as plotted on the chart. Below the sectional pressures is a plot of drier surface temperatures at the time of our record run. It will be noted

that there are increasing temperatures from driers nos. 1 through 15 which is the entire first section. This increasing temperature, which is partially attributed to the design of the forced vapor system, indicates the probable number of driers the sheet was required to traverse before the stock-water mixture absorbed sufficient heat to bring the moisture to the flash point, the requirements, from this point on until the sheet was well in the sixth section, being to supply enough heat to maintain the flash condition are evidenced in the tendency for the surface temperature curve to level out. In the sixth section, starting at about the 11th drier back from the last drier, the tendency for the surface temperature curve to rise is evidence that the sheet had reached a point in dryness where there was less demand for heat which caused an increase in drier surface temperature due to design of the forced circulation system.

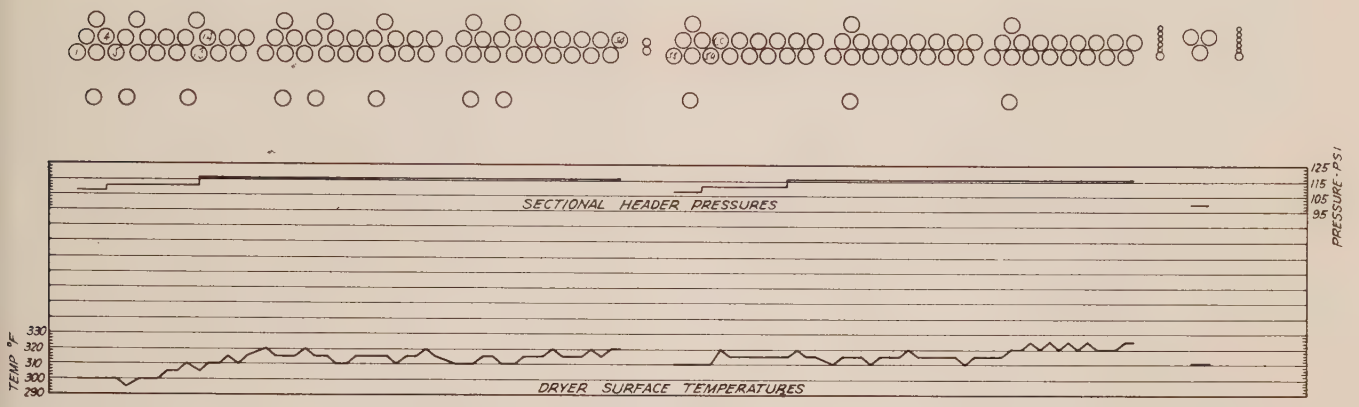

Fig. 1. Drier arrangement—pressure and temperatures

HOOD AND AIR SUPPLY

The problem of removing water from the sheet, as was stated above, can be divided into three basic operations. The handling of the pounds of water per ton of paper at the wet end and on the presses in quantities which will be given later, for this operation, presents problems which are much easier than that of the disposal of the relatively small percentage removed at the driers. The volume of a pound of water in the liquid state is one thing and in the vapor state another.

The supplying of air and disposal of vapor from this machine operating in excess of 800 tons per 24 hours called for supplying heating and ventilating air and the exhausting of volumes of vapor-laden air that surpasses any paper machine installation to date.

The machine is housed in a steel and brick building 666 feet long by 119-feet wide having openings at one end and along one side to provide means of ingress and egress from the machine basement to loading platforms for use of the shipping department. Because of the necessity of having some of these doors open at all times during all seasons and in view of the humidity conditions which exist in this locality it was deemed necessary to supply make-up air to the machine room which could be controlled in temperature in quantities sufficient to minimize entry of unconditioned air. As a result, the system as supplied gives a machine room air balance of 77%.

The drier section of 102 paper driers and 22 felt driers is completely covered by a standard panel construction hood having structural steel frames to which are attached asbestos board sheets. The hood has wide overhang and deep curtains to insure catching vapors and is of the supported type. There are fifteen outlet connections from the hood, to which are attached 15 72-inch Axiflow fans for exhausting moisture-laden air to atmosphere at the rate of 1,160,000 c.f.m. The hood is 354 feet long and 30-feet wide, the longest paper machine hood in the world.

The heating and ventilating system is divided into four parts with supply fans located along mezzanine floors at approximately the center of the area served by each system. Entering air from outside is filtered and passed through a bank of extended surface heaters having copper tubes and aluminum fins designed to heat air to temperatures of 100° to 115°F. The supply ducts are located in the trusses above the crane passage. Four Silentvane fans provide air to this system at the rate of 240,000 c.f.m.

Eight 72-inch Axiflow fans, comprising the make-up system, draw air from outside through filters and across a bank of heaters to heat it from 20 to 105°F. This air is merely dumped into the machine room to help maintain the air balance of 77%. These fans provide a total of 520,000 c.f.m. Two Grewin systems to provide hot, high velocity air to the drier pockets as a scouring agent for breaking up moisture-laden vapor films on the sheet surface take their supply from the machine room air through a filter and across a three-section, fin-type heater of special air-tight construction. Air is introduced to the drier pockets by means of 45 drops along the backside and 45 along the frontside of the machine. This system is equipped with centrifugal compressors and supplies a total of 4200 c.f.m.

The felt supply system composed of two units draws its supply from outside the machine room through filters and across an extended surface heater bank which gives the air a temperature of 140 to 160°F. This air is directed on the surface of the felt by means of nozzles, 50% being directed to the middle third of the felt. A volume of 130,000 c.f.m. is required, and this air is all directed against the bottom felts which, because of the run through the basement, are subject to cooling with its resultant moisture retention.

A calender cooling system designed to handle 12,000 c.f.m. and a motor cooling system accommodating 752 hp. and handling 6556 c.f.m. are also used.

This gives for the machine a total volume of air handled of 2,072,756 c.f.m.

Steam for heating of air is provided at 40 p.s.i. as exhaust steam from a turbogenerator, which also provides 40 p.s.i. process steam for other parts of the mill.

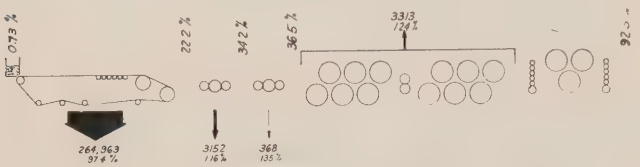

Fig. 2. Water removal on the paper machine

Heater banks are provided with traps for condensate and air removal, which discharge to the paper machine condensate cooler, and thence to the low-pressure steam separator where air and noncondensable gases are removed and the condensate returned to the power plant for reuse as boiler feedwater.

POWER SUPPLIED

The paper machine is driven by a 2000-hp. turbine-gear set, mounted in the center of a lineshaft in the basement. From cone pulleys on the lineshaft power is transmitted by flat belts to cone pulleys on right-angle mechanical drive units mounted at the main couch, first dual press, second dual press, six drier sections, breaker stack, first and second calenders and at the reel. In addition, on one end of the lineshaft is mounted three d-c. generators with a total rating of 400 kw. and an additional motor-driven 25-kw. set for supplying power to d.-c. helper motors of 100 hp. on the primary couch, 100 hp. on main couch, 100 hp. on first dual press, 100 hp. on second dual press, and 25 hp. on the top breaker stack roll. The designed horsepower input to the machine by sections is as follows:

Primary couch	100 hp. (100-hp., d.-c. motor)
Main couch	325 hp. (225-hp. belt, 100-hp. motor)
First dual press	176 hp. (76-hp. belt, 100-hp. motor)
Second dual press	176 hp. (76-hp. belt, 100-hp. motor)
First drier section	98 hp. (belt)
Second drier section	98 hp. (belt)
Third drier section	91 hp. (belt)
Breaker stack	67 hp. (42-hp. belt, 25-hp. motor)
Fourth drier section	76 hp. (belt)
Fifth drier section	76 hp. (belt)
Sixth drier section	76 hp. (belt)
First calender	125 hp. (belt)
Second calender	135 hp. (belt)
Reel	38 hp. (belt)

The total horsepower of synchronous motors at the machine at the time of this record run was 1375 hp., of d.c. 546 hp., and induction motors 1243 hp.

OPERATING CONDITIONS

During the period of 24 hours from 8:00 a.m., April 15, to 8:00 a.m., April 16, the following average of operating conditions was in effect:

Basis weight	69 lb. per 1000 sq. ft.
Caliper	0.0195 in.
Machine speed	1045 f. p. m.
Trim between squirts	210 in.
Reel width	202¾ in.
Freeness—Canadian Std., 3 grams at 20°C.	658
Headbox consistency	0.73%
Tons per hour over driers	36.14
Tons per hour finished	34.95
Drier steam	246,583, lb. per hr.
Heater steam	39,620, lb. per hr.
Moisture to first press	77.8%
Moisture to second press	65.8%
Moisture to driers	63.5%
Moisture to reel	7.7%

WATER REMOVAL

Figure 2 relates graphically the story as well as the problems of water removal when producing board in excess of 800 tons per day. The quantities of water removed at various points along the machine were computed from a series of moisture checks at the various sections under the above conditions one day previous to April 15 when the 24-hour production was 813 tons, and these figures are believed to be reasonably close to those of April 15. On this basis, with 0.73% moisture-free stock to the wire and assuming the water to the wire as 100%, we find that 271,972 pounds of water per ton of stock were coming to the wire. Of this amount 264,963 pounds per ton, or 97.4%, was removed by natural drainage and by vacuum at the flat boxes and two couches; .3152 pounds of water per ton of stock, or 1.16%, was removed at the two suction press rolls on the first dual press, what the distribution was between the first and second rolls is not known; 368 pounds of water per ton of stock, or 0.135%, was removed at the second dual press which, as noted above, consists of one suction roll and one smoothing press. Water removed in the driers amounted to 3313 pounds per ton, or 1.24%. This leaves remaining in the sheet 166 pounds per ton or 0.06%, all calculations being on a moisture-free basis.

On the basis of 36.14 tons per hour over the driers, 19,255 g.p.m. were brought to the wire or 82.5 tons per minute. Of this quantity 19,169 g.p.m. were removed at the wire or 79.5 tons per minute; 227.9 g.p.m. or 0.94 ton per minute at the first dual press; 26.7 g.p.m. or 0.11 ton per minute at the second dual press, and 240.4 g.p.m. or 0.997 ton per minute in the driers.

During the 24-hour period 118,800 tons of water were put to the wire, 114,480 tons removed at the wire, 1353.6 tons removed at the first dual press, 158.4 tons removed at the second dual press, and 1435.68 tons were removed as water vapor from the drier hood along with 60 tons of air per ton of board.

DRYING RATE

Drying rates were calculated according to standards set up by TAPPI Heating and Ventilating Committee, all calculations being on an air-dry basis.

Full value was given to the 102 paper driers, three calender driers, and to only 21 of the 22 felt driers as the sixth bottom section was operated at that time without a felt.

Drying rate calculations were as follows.

$$s/w = \text{drying surface in square feet per inch width}$$
$$= 0.0218\,(NpDpt + NfDf)$$
$$= 0.0218\,((105)(60) + (21)(60))$$
$$= 164.81$$

$$Rp = \text{pounds of paper dried per hour per square foot of drying surface}$$
$$= \frac{Sm \times B}{(s/w) \times K}$$
$$= \frac{1045 \times 69.0}{164.81 \times 200}$$
$$= 2.12$$

M = pounds of water evaporated per pound of paper as dried

$$= \frac{L}{E} - 1$$

$$= \frac{92.3}{36.5} - 1$$

$$= 1.52$$

Rw = pounds of water evaporated per square foot of drying surface

$$= Rp \times M$$

$$= 2.12 \times 1.52$$

$$= 3.22$$

Further values of Rp and Rw were computed on other grades at less tonnage to try to check an extension, on the same slope, of the 1939 paperboard average production drying rates and evaporation drying rates as established by Montgomery. Figure 3, the evaporation drying rate curve, would seem to confirm the slope of the original curve while Fig. 4, production drying rate, would seem to indicate a somewhat less slope than originally determined.

The scope of this paper is not intended to confirm or deny the original slope, but purely as a matter of interest to indicate in which direction the trend may be in view of the total number of driers and steam pressures involved on our machine.

CONCLUSION

As has been noted above, a very great percentage of the initial water to the machine is removed on the wire section with lesser amounts at the suction presses, the remainder being removed by evaporation at the driers and exhausted to atmosphere. The increasing speeds at which board is being produced, in connection with water removal as shown in this paper, can only indicate

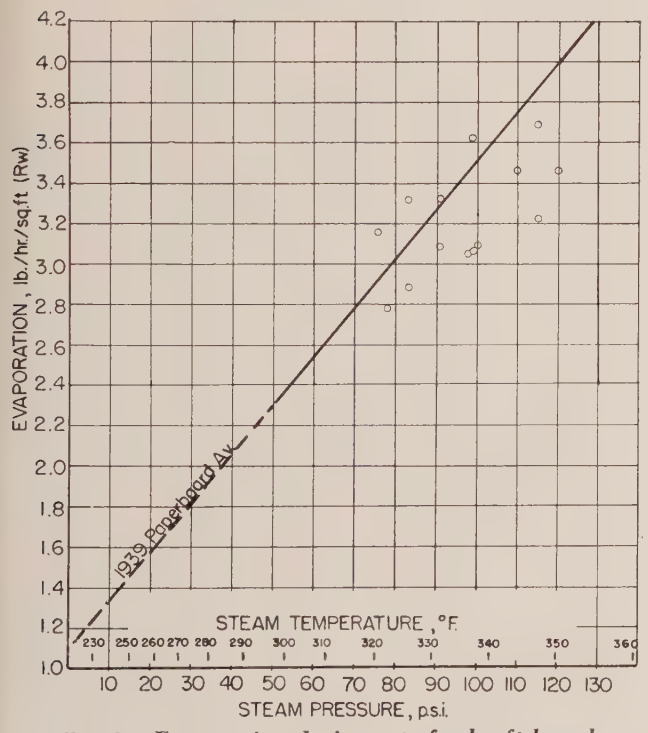

Fig. 3. Evaporation drying rate for kraft board

longer drying sections to evaporate the comparatively small percentage of water remaining in the sheet after the presses. The capital expenditure for drying capacity on these machines is very heavy as is also the expenditures for building space and air removal equipment. Any water which can be removed ahead of the driers will have a tendency to alter this trend. It appears that the machine designer has the problem ahead of him of improving present means or devising newer ways of more efficient water removal ahead of the driers. The machine operator can increase the quantity of drying on existing machines by taking best advantage of

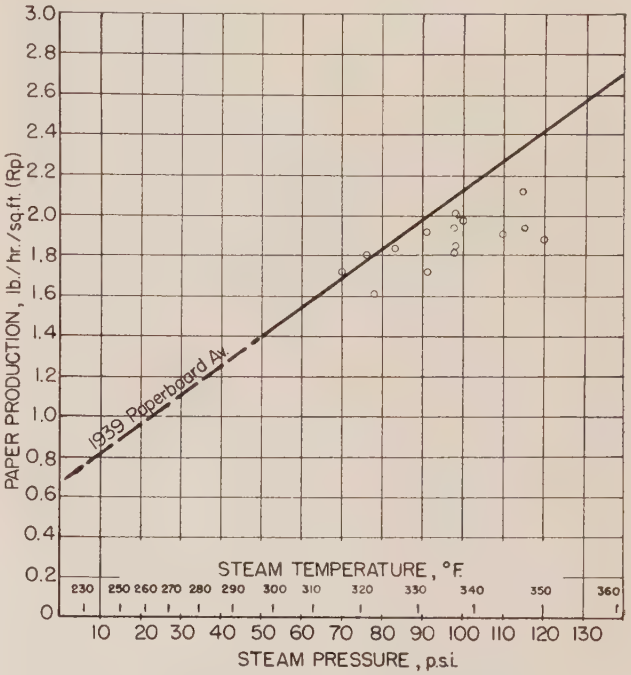

Fig. 4. Production drying rate for kraft board

equipment on hand. Proper maintenance of suction press rolls to allow them doing, at all times, their part in water removal, siphons within the drier in proper working order at all times in connection with proper water removal, and noncondensable removal equipment in good shape should pay dividends in tons per day over the driers.

We cannot forget the stock applied to the wire. A free stock will lose more water by natural drainage which decreases the ultimate load to the driers, therefore careful consideration should be given the stock preparation process. The wire manufacturer may have a stake at this point, in investigating wires which will not only give the sheet as desired but allow drainage of all water possible.

In the drier section, it is probable that the drier felts themselves have as much effect on drying as any other factor. Does vapor leave the sheet and escape through or to the drier felt, or is the temperature of the liquid brought to a point, under the felt, where it flashes in the space from the leaving of one felt to the entering of another? Could drying rates be improved by the use of more open felts to allow more moisture to leave the sheet immediately upon reaching the flash point?

These are points that should be considered in drying large tonnages of board on one machine.

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Configuration and Structure of Cellulose Xanthate

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An equilibrated viscose solution, prepared in the laboratory by standard procedures, was studied to determine configuration and structure of the cellulose xanthate. The main results are summarized as follows: average degree of substitution, $D = 0.721$; glycol groups per glucose unit, $G = 0.525$; free glucose, $g_0 = 0.279$; monoxanthate, $g_m = 0.721$; dixanthate, g_d = trace; trixanthate, $g_t = 0$; xanthate groups at position 6, $X_6 = 0.243$; xanthate groups at position 2, $X_2 = 0.270$; xanthate groups at position 3, $X_3 = 0.208$; glucose anhydride 6-xanthate, $C_6 = 0.243$; glucose anhydride 2-xanthate, $C_2 = 0.270$; glucose anhydride 3-xanthate, $C_3 = 0.208$; and free glucose anhydride, $C = 0.279$.

Although the viscose rayon industry is well established, there is still a great lack of fundamental knowledge about cellulose xanthate. The distribution of the xanthate groups in cellulose xanthate and their position in the glucose residue are still undetermined. In the industry, a normally prepared commercial viscose contains about one xanthate group for every two glucose residues, that is, one hydroxyl in every six is esterified. The various possibilities of the distribution of the xanthate groups in the (usual) cellulose xanthate are discussed by Heuser (*11*).

If the viscose is a mechanical mixture of cellulose xanthate and cellulose, it should be possible to separate it into fractions with widely differing sulphur contents. If the xanthate groups are distributed rather uniformly over the chains, such separation into fractions of differing sulphur contents would not be possible.

To study the position of xanthate groups within the glucose units, it is desirable to convert the cellulose xanthate into a stable compound which will have the same distribution of substituent groups as the cellulose xanthate. This is necessary since the xanthate is quite unstable. Although methyl chloroacetate and N-diethylchloracetamide react to form stable compounds with the cellulose xanthate, these compounds can hardly sustain the vigorous chemical treatments necessary for further study of their location, such as acid hydrolysis, tosylation, iodination, oxidation, etc., without undergoing chemical change. The ether linkage is quite stable toward these reactions. Therefore, a modification of Lieser's method (*18, 19*) was used to convert the xanthate into methyl cellulose.

When the location of xanthate groups in the glucose residues is considered, there are eight possible combinations in a partially esterified cellulose xanthate. Since each glucose unit has available three hydroxyl groups at positions 2, 3, and 6, it can form three monoxanthates, three dixanthates (2,3; 2,6; and 3,6) and one trixanthate, or it may remain a free glucose unit.

PREVIOUS WORK

This problem of the structure of cellulose xanthate was first attacked by Lieser in 1928, who converted xanthate into a partially methylated cellulose. Upon acetolysis, a mixture of cellobiose and methyl cellobiose acetates should result. Lieser (*18*) obtained only about 50% cellobiose octaacetate. No mono or dimethylcellobiose acetate should be detected. No decisive conclusion about the distribution of xanthate groups along the cellulose chain can be drawn from this result. Lieser (*19*) later reported that all the xanthate groups were at position 2 by comparing the phenylhydrazine derivative of the methyl glucose (obtained by converting cellulose xanthate into a partially methylated cellulose derivative and hydrolyzing it with 75% sulphuric acid) with a synthetic dimethyl glucose phenylhydrazone. Unfortunately, the yield of dimethyl glucose obtained by hydrolysis of the methyl cellulose was very small. In 1934, Fink and his coworkers (*8*) were able to fractionate the viscose into several fractions with slightly different sulphur contents by ultrafiltration.

Further work on the structure has been carried out and reported by Lieser and Leckzyck (*20*) and by Lieser and Jaks (*21*). Rassow et al. (*25*) suggested that the hydroxyl groups in the 6-position are preferred but furnished no experimental evidence of this assumption. Heuser (*12*) concludes that "all that can be said at present is that possibly a small percentage of the xanthate groups are located in the 2-position."

Special techniques have been used to increase the degree of substitution of xanthate groups per glucose unit. Geiger (*9*) reports that, using a great excess of carbon disulphide, 1.5 xanthate groups per glucose unit were obtained. Jimbo and Takada (*16*) obtained 1.1 xanthate groups per glucose unit by similar means.

While it is not feasible to attempt complete coverage of the literature, several other references are worthy of note. Danilov (*5*) describes the determination of the degree of substitution by use of chloroacetonitrile. Staudinger and Zapf (*33*) discuss methods of xanthation, with subsequent methylation and hydrolysis. Scherer and Miller (*28*) and Scherer and Phillips (*29*) report on the distribution of xanthate groups in fractions of varying degrees of polymerization.

MATERIALS AND PROCEDURE

Raw Material

The cotton linters pulp in fibrous form was obtained from the Hercules Powder Co., and was a special grade of low D.P. pulp.

The moisture content was determined by drying at 105°C. for 24 hours. The alpha-cellulose was determined by the volumetric method of Bray and Andrews (*2*). Ether extraction was carried out in a Soxhlet apparatus for 24 hours with ethyl ether. The intrinsic viscosity was evaluated by extrapolating the curve of η_{sp}/c against c to zero concentration in cupriethylenediamine solution and the degree of polymerization esti-

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Table I. Analysis of Cotton Linters Pulp

Moisture	4.70%
Alpha-cellulose (dry basis)	95.80%
Ether extraction	0.07%
Ash	0.05%
Copper number	0.70
Intrinsic viscosity	3.00
Degree of polymerization	780

mated from Kraemer's constant (*17*). The copper number was determined by Clibbens and Geake's method (*7*).

Fractionation of Cellulose Xanthate

Fractionation of Freshly Prepared Viscose Solution. Ten grams of cotton linters pulp were steeped in 150 ml. of 18% sodium hydroxide solution at room temperature for 2 hours. The pulp was pressed to 35 grams (P.W.R. = 3.5) and allowed to stand in a stoppered bottle for 3 days at room temperature. The aged alkali cellulose was shaken with 10 ml. of carbon disulphide for 4 hours at about 25°C. The cellulose xanthate was washed with absolute methanol until a colorless filtrate was obtained and pressed at 1000 p.s.i. for 5 minutes. Twenty-nine grams of the purified wet product were obtained. Three grams of the product were used for analysis for sulphur and cellulose and 26 grams were dissolved in 150 ml. of 4% sodium hydroxide solution for fractionation. Each fraction was precipitated by the addition of successive portions of saturated sodium chloride solution and separated from the mother liquor by centrifuging. The mother liquor in the precipitated solid was further removed by blotting with sheets of cotton linters. The samples were analyzed immediately for cellulose and sulphur. The whole operation of fractionation was accomplished within 6 hours.

Fractionation of Ripened Viscose Solution. The solid cellulose xanthate was prepared by the method mentioned above. After removing the excess of carbon disulphide by suction, the cellulose xanthate was dissolved in 4% sodium hydroxide solution to form a viscose containing 7% cellulose. The viscose was aged for 4 or 8 days at 18 to 20°C. The ripened viscose was purified by precipitating and washing with absolute methanol to remove all of the inorganic sulphur compounds. The purified cellulose xanthate was dissolved again in 4% sodium hydroxide solution and fractionated into several fractions by addition of successive portions of saturated sodium chloride solution. In the second of these experiments, the degree of polymerization, the combined sulphur, and the cellulose content were estimated for each fraction.

Methods of Analysis. Cellulose was estimated according to the procedure given by Doree (*7*) using a 4 to 6-gram sample instead of a 0.5-gram sample. For determining combined sulphur, 3 grams of the sample were shaken with 20 ml. of absolute methanol several times and filtered with the aid of suction. The purification was repeated until a colorless filtrate was obtained in the suction flask. The excess methanol was pressed out. A 0.5-gram portion of the purified sample was dissolved in 100 ml. of 4% sodium hydroxide solution and oxidized by an excess of bromine water. The sulphate formed by oxidation was precipitated with barium chloride, and calculated to combined sulphur.

CONVERSION OF CELLULOSE XANTHATE TO METHYL CELLULOSE

A satisfactory method of converting the cellulose xanthate into methyl cellulose should fulfill the requirements that all xanthate groups are replaced by methyl groups and that no other methyl groups are introduced into the cellulose molecule. Diazomethane (nitrosomethylurethan) was used as the methylating agent in this investigation, following the original procedure of Lieser (*18, 19*).

Three materials were used in the preliminary experiments to test the reliability of the methylation process: original cotton linters pulp, alkali cellulose washed with absolute methanol until it was neutral to phenolphthalein, and cellulose regenerated from alkali cellulose. Two cellulose xanthates were used: (1) an alkali cellulose xanthate and (2) a neutral cellulose xanthate. The alkali cellulose xanthate was obtained by triturating a normally prepared cellulose xanthate with absolute methanol, washing it repeatedly with absolute methanol until a colorless filtrate was obtained, and removing the excess methanol by pressing. The neutral cellulose xanthate was prepared from crude normally prepared cellulose xanthate by washing the sample twice with absolute methanol, neutralizing it with 10% acetic acid in methanol at 0°C., and washing it with absolute methanol to remove any residual acid.

A 1-gram portion of any given sample was soaked in 50 ml. of cold absolute methanol and cooled in an ice-water bath. Twenty milliliters of nitrosomethylurethan, dissolved in 20 ml. of absolute methanol, were added gradually during a half-hour period from a dropping funnel with vigorous stirring. The mixture was kept between 5 and 8°C. during the addition of the methylating agent and allowed to react for 5 hours. The methylated sample was filtered through a coarse sintered glass filter, washed thoroughly with ethyl alcohol and water, and then dried at 105°C.

The sulphur and cellulose contents of the cellulose xanthate were estimated by the methods mentioned above. The methoxyl content of the methyl cellulose was determined according to the procedure given by Samsel and McHard (*27*) with the addition of a trap containing a 5% cadmium thiosulphate solution to absorb the free iodine, hydrogen iodide, and hydrogen sulphide in the gas stream.

DETERMINATION OF STRUCTURE OF METHYL CELLULOSE

There are eight possible configurations in a partly esterified cellulose xanthate. In order to find the relative amounts of these possible configurations, eight sets of data, at least, are required. A schematic outline of the whole determination is shown in Fig. 1.

Preparation of Methyl Cellulose

Thirty-two grams of cotton linters pulp were steeped in 400 ml. of 18% sodium hydroxide solution for 2 hours at 23°C. After pressing to 94 grams, the alkali cellulose was allowed to age for 3 days and xanthated with 24 ml. of carbon disulphide for 4 hours at room temperature. The cellulose xanthate was purified by dissolving the crude product in 345 ml. of 4% sodium hydroxide solution within a period of 3 hours and precipitating the purified product by the addition of 1.5

liters of methanol. The precipitate was washed three times with 200-ml. portions of absolute methanol and steeped in 380 ml. of cold 5% acetic acid in methanol to remove the excess alkali. After removing the acetic acid, the precipitate was washed thoroughly with absolute methanol until the washings were free from acid. A one-sixteenth portion of the purified xanthate was reserved for analysis and the balance was suspended in 750 ml. of cold absolute methanol. The suspension was cooled in an ice-salt bath to keep the temperature of the mixture at 5 to 8°C. and methylated with 600 ml. of nitrosomethylurethan in 600 ml. of absolute methanol for 5 hours with vigorous stirring. The methyl cellulose was filtered out on a Büchner funnel and washed repeatedly with dry ethyl alcohol until the precipitate was free from mercaptans and water. The purified methyl cellulose was dried at 105°C. to constant weight.

Determination of the Number of Glycol Groups per Glucose Residue (23, 34)

One hundred milligrams of methyl cellulose were carefully weighed and added to 50 ml. of 0.05 *M* sodium paraperiodate solution, which contained 20 grams of acetic acid per liter. The mixture was allowed to stand at room temperature for 70 hours, which time was estimated from the data of Barry and co-workers (*1*). The excess periodic acid was estimated by titration with standard arsenite solution.

Estimation of Free Glucose by Fermentation

The methyl cellulose was first hydrolyzed with 72% sulphuric acid into glucose and methyl glucoses according to the procedure given by Timell (*34*). The free glucose was estimated according to the procedure given by Schultz (*30*) with some modifications. Eight and eight tenths grams of sample were dissolved in a small volume of water. The solution was diluted to 250 ml. after adding a yeast paste made of 20 grams of baker's yeast and water. The fermentation was carried out at 34 ± 1°C. and allowed to continue until the weight of the Ascarite tube (collecting the CO_2) was constant. After removing the yeast by centrifuging, the clear solution was evaporated almost to dryness. The residue was repeatedly purified by extracting with absolute methanol and boiling with activated carbon. Finally, the product was dried under vacuum (40 mm. pressure) at 105°C. (yield 5.3 grams) and its methoxyl content was determined. The amount of free glucose was calculated from the amount of carbon dioxide evolved. A blank test and standardization of this method, using chemically pure dextrose, were carried out under the same conditions.

Estimation of Mono, Di, and Trimethyl Glucoses

The methyl glucosides of the unfermentable methyl glucoses were prepared by refluxing with 1.12% methanolic hydrogen chloride and an attempt made to fractionate them according to the procedure given by Timell (*34*). The distillation was stopped after 3 hours because no liquid distilled over. The yellow liquid in the column was washed out with methanol and dried under vacuum at 74°C.; 0.118 gram of glucosides from the washings was obtained from 4.70 grams of sample. The methoxyl contents of the still residue and of the washings from the column were each determined.

Estimation of Free Primary Hydroxyl Groups (13, 23, 24, 35)

1. Tosylation. Two grams of the dry methyl cellulose were "tumbled" overnight with 30 ml. of pyridine and 10 ml. of water. The mixture was evaporated under high vacuum, at a temperature below 80°C., and washed four times with 50 ml. of anhydrous pyridine in order to remove all moisture, as this reaction needs to be carried out under anhydrous conditions. The treated sample was added to 90 ml. of carefully dried pyridine, in which 25 grams of purified *p*-toluenesulfonyl chloride had been dissolved. The mixture was kept at 25°C. in a thermostat with constant stirring. After 171 hours the mixture was diluted with 500 ml. of diethyl ether and washed three times with additional diethyl ether by decantation. The remaining pyridine and salt were removed by maceration with 70% methanol. The sample which had an ivory color was dried at 74°C. *in vacuo* over calcium chloride (yield 3.5 grams). The product was analyzed for sulphur and methoxyl.

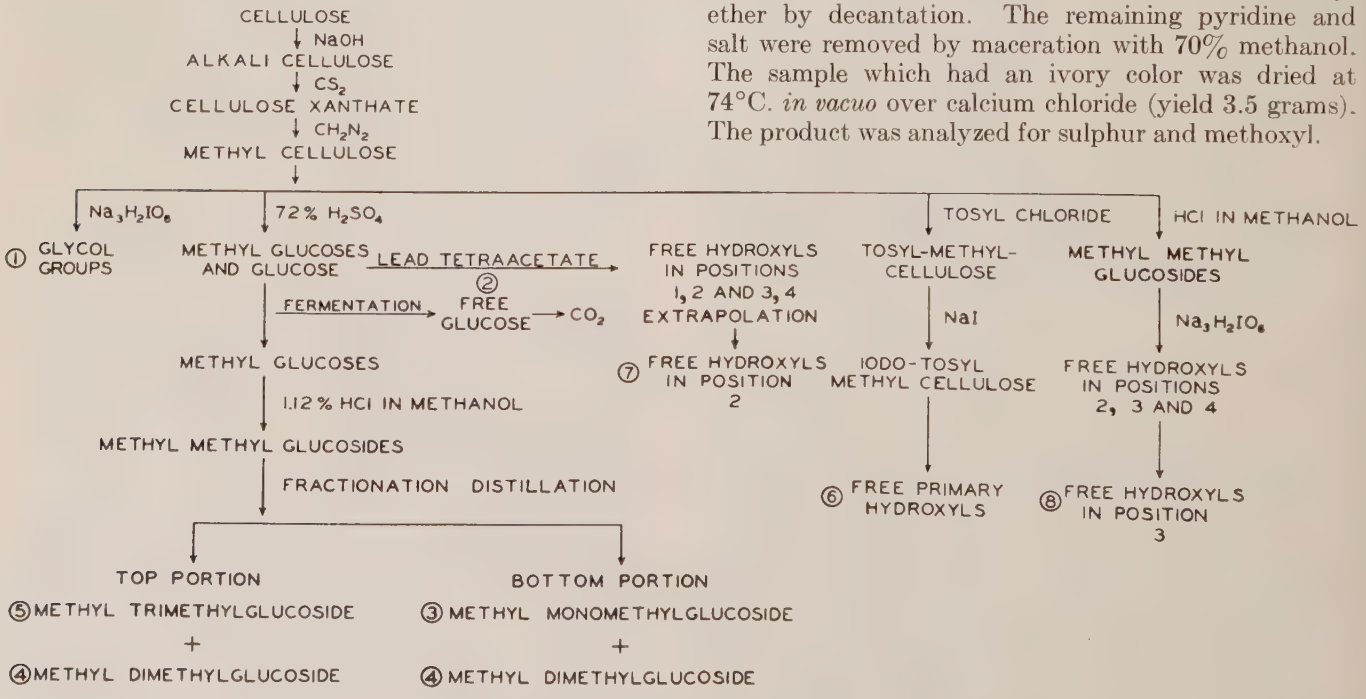

Fig. 1. Scheme of procedure

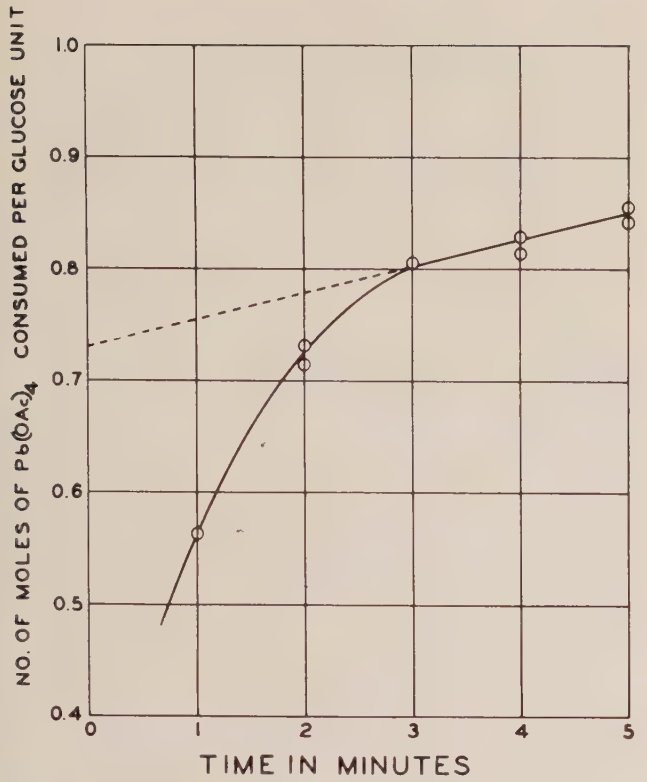

Fig. 2. Oxidation of methyl glucoses with lead tetraacetate

2. Iodination. One and a half grams of the tosylated methyl cellulose were added to a solution of 2.5 grams of sodium iodide in 50 ml. of acetonylacetone and the mixture was heated for 2 hours at 120°C. in an oil bath. After rapid cooling, 300 ml. of diethyl ether were added to the mixture. The product was washed several times with aqueous methanol and further purified by maceration with aqueous methanol and 0.1 *N* sodium thiosulphate solution. After washing with water, methanol, and diethyl ether, the faintly yellow product was dried under vacuum. The product was analyzed for methoxyl, sulphur, and iodine.

3. Analysis of Product. *Sulphur:* The sample was fused with sodium peroxide according to the procedure given by Mahoney and Michell (*22*). The sulphate in the solution was estimated as barium sulphate after removal of the peroxides and acidification with hydrochloric acid. *Iodine:* Iodine was determined as silver iodide by the Parr bomb method according to Shriner's procedure (*31*).

Estimation of Free Hydroxyl Groups in Position 2

The experiment was carried out according to the method of Timell (*34*). The number of glycol groups oxidized per glucose residue, calculated from the number of moles of lead tetraacetate consumed, was plotted against the time of reaction. The free hydroxyl in position 2 of the methyl cellulose was obtained by extrapolating the straight-line portion to zero time. The oxidation curve is shown in Fig. 2.

Estimation of Free Hydroxyl Groups in Position 3

Seven-tenths gram of methyl cellulose was hydrolyzed into methyl glucosides according to the method of Irvine and Hirst (*14*) with the modification of Timell (*34*). Fifty milligrams of the sirup were weighed into an Erlenmeyer flask. Fifty milliliters of 0.05 *M* solution of sodium paraperiodate containing 20 grams of acetic acid per liter were added to the flask. The solution was allowed to stand at room temperature for 24 hours. The excess of sodium paraperiodate was determined with 0.05 sodium arsenite solution.

RESULTS AND DISCUSSION

Distribution of Xanthate Groups Among the Cellulose Chains

Table II shows that a freshly prepared cellulose xanthate of an average degree of substitution of 0.57 was fractionated into three fractions with degrees of substitution varying from 0.494 to 0.636. Another freshly prepared cellulose xanthate with an average degree of substitution of 0.427 was fractionated into four fractions with degrees of substitution varying from 0.379 to 0.474. If the variation of the degree of substitution is due to analytical error, those differences should be within the maximum error of the method of analysis which is below 1% and the variation should be of a random form. The present results show that the differences in the degree of substitution among the fractions vary from 4 to 21% and that the variation in the degree of substitution is in a definite increasing order. These results show that the xanthate groups in a freshly prepared cellulose xanthate are not uniformly distributed over all chains of the cellulose. It does not necessarily mean that the freshly prepared xanthate is a mechanical mixture of completely xanthated cellulose and unreacted cellulose. If it were a mechanical mixture, the variation in degree of substitution should be much larger than the present figures indicate. The most reasonable explanation is that the cellulose chains are xanthated to widely different degrees of substitution. The cellulose chains on the outside of the fiber may be xanthated to a higher degree of substitution and the inner part of the fiber may have a lower sulphur content. Scherer and Phillips (*29*) arrived at a similar conclusion. The results of fractionation show that xanthation has the characteristics of a topochemical-macroheterogeneous reaction.

The results on the fractionation of two ripened viscose solutions (Table II) indicate that, during ripening, the xanthate groups in the viscose change from an uneven distribution to a more uniform one. This change can be accomplished either by the splitting off of some xanthate groups or a combination of the splitting off of carbon disulphide and rexanthating other unreacted hydroxyl groups. According to Centola's work (*3*) this change is due to dexanthation and rexanthation. In Item 3 of Table II, viscose, of an average degree of substitution of 0.563, had an average distribution of only slightly above 0.30 after ripening. These results indicate that the more uniform distribution of xanthate is accomplished by splitting off of xanthate groups (loss of carbon disulphide) with little recombination with free hydroxyls (rexanthation).

Conversion of cellulose xanthate to methyl cellulose

It is quite interesting to note that every 0.1 gram cotton linters pulp consumes 0.51 ml. of 0.1 *N* sodium thiosulphate solution which corresponds to 0.29% methoxyl group. When this pulp is treated with nitrosomethylurethan in the absence of alkali, the product contains 0.30% of methoxyl, which is about the same as

Table II. Fractionation of Cellulose Xanthate

Sample	Original	Degree of substitution (xanthate groups per glucose unit) — Fractions I	II	III	IV	V	VI
Fresh viscose[a]	0.57	0.494	0.525	0.636			
Fresh viscose[a]	0.427	0.379	0.405	0.421	0.474		
Ripened viscose[c]	0.563[b]	0.301	0.302	0.302	0.311	0.297	0.333
Ripened viscose[d]	0.221	0.218	0.222	0.216	0.223		

[a] Before ripening.
[b] Determined before ripening.
[c] Ripened for 4 days.
[d] Ripened for 8 days.

the untreated pulp. Based on this fact, it can be concluded that the nitrosomethylurethan does not methylate the cellulose in the absence of alkali.

The results are quite different if the pulp is first converted into alkali cellulose. The alkali cellulose, which shows an apparently neutral reaction to phenolphthalein by repeated washing with absolute methanol, still can be methylated by nitrosomethylurethan without the addition of more alkali to give a product containing 4.31 to 5.00% methoxyl. This shows that the free or combined alkali cannot be removed completely from the alkali cellulose by washing with alcohol and that the washed alkali cellulose is readily methylated with nitrosomethylurethan. If the alkali cellulose is washed with dilute acetic acid and methanol to remove all the alkali, the product from methylation gives 0.42% methoxyl, which is close to the measured methoxyl content of the untreated pulp.

In the methylation of the alkali cellulose xanthate, the methoxyl contents found in the samples are always higher than the theoretical value. This indicates that the diazomethane, in addition to replacing the xanthate groups, can methylate the alkali cellulose which is coincident with the results of methylation of alkali cellulose. In experiments CA-1 and CA-2, the actual methoxyl contents are about 31 to 58% higher than the theoretical values when the methylation was carried out at a maximum temperature of 20°C. for about 10 minutes. In experiment CA-3, the actual value is lower than the theoretical ethoxyl content because the temperature was kept at 2 to 3°C. during the methylation period and the cellulose xanthate was in a lump form. In experiments CA-4 and CA-5, the actual and theoretical methoxyl contents are rather close to each other, but CA-5 still has an error of about 10%.

Based on the above facts, at least two reactions occur simultaneously when an alkali cellulose xanthate is treated with nitrosomethylurethan: (1) replacement of the xanthate groups and (2) methylation of the alkali cellulose. Sometimes the actual value is very close to the theoretical one, but this does not necessarily indicate a quantitative substitution of the xanthate groups because a certain degree of substitution can be obtained by partly replacing the xanthate groups and partly methylating the alkali cellulose to an extent corresponding to the amount of the unattacked xanthate groups in the sample.

The above difficulty can be practically eliminated by using a neutral xanthate. According to a preliminary experiment, acid-washed alkali cellulose will not be attacked by nitrosomethylurethan. Therefore, the methoxyl groups can only be introduced through the replacement of the xanthate groups. This was confirmed by experiments CN-1 and CN-2. The optimum procedure is based on treatment of each gram of cellulose with 20 ml. of nitrosomethylurethan at a temperature of 5 to 8°C. for 5 hours. In CN-4, the conversion of xanthate into methoxyl is quantitative. The theoretical methoxyl content is 10.77%, and the measured value is 10.96%. If a correction for the measured methoxyl content in the original cellulose is made, the measured value becomes 10.69%.

STRUCTURE OF CELLULOSE XANTHATE

Conversion of Cellulose Xanthate into Methyl Cellulose

The number of xanthate groups per glucose unit in the neutral cellulose xanthate sample used in this portion of the study was 0.709 which should give a theoretical methoxyl content of 12.80% but the actual value

Table III. Conversion of Cellulose Xanthate to Methyl Cellulose

Sample		Xanthate groups per glucose unit	Maximum methylation temperature, °C.	Methoxyl content — Found, %	Theoretical,[a] %
Original cotton (Blank linters pulp test)		0	Without methylation	0.29	0
Cotton linters pulp		0	20	0.30	0
Alkali cellulose (washed with methanol)		0	20	5.00	0
Alkali cellulose (washed with methanol)		0	20	4.31	0
Regenerated cellulose (from alkali cellulose)		0	20	0.42	0
Alkali cellulose[b] xanthate	CA-1	0.428	20	12.54	7.91
	CA-2	0.453	20	11.33	8.36
	CA-3	0.540	2–3	8.92	9.95
	CA-4	0.502	2–4	9.54	9.20
	CA-5	0.563	4	11.40	10.28
Neutral cellulose xanthate[b]	CN-1	0.543	2–4	3.26	9.94
	CN-2	0.566	5	7.43	10.33
	CN-3	0.499	20	10.30	9.16
	CN-4	0.591	5–8	10.96	10.77

[a] Correction for the methoxyl content as determined in the blank tests has not been made on the theoretical value.
[b] See "Preparation of Samples."

was 13.03, which corresponds to a degree of substitution of 0.721. After correcting for the initial methoxyl content, the actual value becomes 12.78%. This shows that the xanthate groups are completely converted into methoxyl groups and that no methylation occurs on the free hydroxyl groups. The position and distribution of the methoxyl groups in the sample should thus represent the configuration of the xanthate groups in the original cellulose xanthate.

Glycol Groups in Methyl Cellulose

In the eight experiments, the average value was found to be 0.525 glycol group per glucose unit. The individual values covered a range from 0.46 to 0.60. This shows that the reaction is heterogeneous in character (*10*) and that some side reactions accompany the main reaction (*6*, *10*, *15*, *26*). Some nonhomogeneity of the sample may also be partly responsible for the variation in the results. In a partially substituted methyl cellulose, the reaction of oxidation with sodium paraperiodate should occur only on free glucose units or 6-methyl glucose anhydride in which the positions 2 and 3 are free. Therefore, the number of glycol groups per glucose unit should be equal to the sum of the free glucose anhydride and 6-methyl glucose anhydride. The difference between unity and glycol groups per glucose unit should be either equal to or smaller than the sum of the methoxyl groups in the positions 2 and 3.

Free Glucose

The measured methoxyl content in the methyl glucose was 11.85% while the theoretical value calculated from the methyl cellulose is 11.88%. This shows that no methoxyl groups were removed in the acid hydrolysis. Free glucose in the hydrolyzed product was about 29.1% calculated from the amount of carbon dioxide evolved during fermentation. The residue contained 14.11% of methoxyl groups which is lower than the calculated 16% for monomethyl glucoses. This may be due either to incomplete removal of the free glucose or to contamination from impurities in the yeast mixture. If the fermented product contains free glucose, the methoxyl content of the corresponding methyl glucosides calculates to be 28.1%. If the inert impurities from the yeast are present in the product, the methyl glucosides calculate to 26.3% methoxyl groups, which is very close to the measured value of 26.4%. Therefore, the low methoxyl content is due to the presence of inert impurities rather than to unfermented glucose.

Mono, Di, and Trimethyl Glucosides

No distillate was obtained on the fractionation of the methyl glucosides. The liquid from the fractionating column contained 30.5% of methoxyl, and the residue contained 24.6%. For dimethyl methyl glucoside, the methoxyl calculated would be 41.9% and for a monomethyl methyl glucoside 29.8%. Thus, the sample from the column can contain only 0.15% of methyl dimethyl glucoside and it is very likely that it contains no trimethyl methyl glucoside. It would appear more reasonable to assume that the mixture contains a trace of dimethyl glucosides.

According to the above result, the cellulose xanthate contains almost no di and trixanthates. The ratio of free glucose to total number of glucose residues is equal to the difference between unity and the degree of substitution, i.e., 1−0.721 (degree of substitution) = 0.279 free glucoses per total glucose units.

Free Primary Hydroxyl Groups

After tosylation, the methoxyl contents in the two samples were 5.64 and 5.56%, respectively. This shows that no methoxyl group was removed during tosylation. The tosyl groups in the tosylated samples were 1.430 and 1.488 per glucose unit, respectively. The total degree of substitution was 2.151 per glucose unit in the first sample and 2.209 in the second sample. This means that the primary hydroxyls were completely substituted and that the two secondary groups were partly substituted. This is the necessary condition for the determination of the free hydroxyl groups by this method.

After iodination, the iodine content was 0.757 atom per glucose unit in the first sample and 0.756 in the second sample. The experimental methoxyl content was 0.720 per glucose unit in the first sample and 0.719 in the second sample. This proves no removal of the methoxyl group during iodination. The sum of the tosyl group and iodine shows a small discrepancy between the experimental value of 1.459 and the theoretical one of 1.430 in the first sample. In the second sample the total degree of substitution of tosyl and iodine was 1.508 in comparison with the theoretical value of 1.488.

The free primary hydroxyl groups are equal to the number of iodine atoms. Therefore, the free primary hydroxyl group is 0.757 per glucose unit and the methoxyl group in position 6 is 0.243 by difference.

KINETICS OF OXIDATION OF GLYCOL GROUPS BY LEAD TETRAACETATE

Two kinds of mechanism have been suggested for the oxidation of glycol groups by lead tetraacetate: namely, free radical (*36*) and ester formation (*4*). In the second mechanism, the intermediate compound formation seems to be a slow reaction according to the collision theory and, thus, is rate determining. If the amount of lead tetraacetate is in large excess, its concentration must be nearly a constant and the reaction may be considered as second order. Two equations can be written, one for cis-form and the other for trans-form.

$$-\frac{dx_c}{dt} = k_c x_c^2 \ldots \quad (1)$$

$$-\frac{dx_t}{dt} = k_t x_t^2 \ldots \quad (2)$$

where x is the concentration expressed in glycol groups per glucose unit, k the specific reaction rate, t the time of reaction; $_c$ stands for the cis-form, and t for the trans-form. The following relation can easily be obtained by integrating equations (1) and (2):

$$M = \frac{k_c x_c^{0 2} t}{k_c x_c^0 t + 1} + \frac{k_t x_t^{0 2} t}{k_t x_t^0 t + 1} \cdots \quad (3)$$

where M is the total number of glycol groups oxidized per glucose unit, x_c^0 the initial cis-glycol groups per glucose unit, and x_t^0 the initial trans-glycol groups per glucose unit. If the cis-glycol can be oxidized very rapidly, the first term on the right side of equation (3)

reaches a constant after a short time of reaction. This constant can easily be proved to be equal to x_c^0.

$$M = x_c^0 + \frac{k_t x_t^{02} t}{k_t x_t^0 t + 1} \cdots \quad (4)$$

In equation (4), if $k_t x_t^0 t$ is much less than 1, a straight line can be obtained by plotting M versus t. The intercept at zero time gives x_c^0 and the slope of the line is equal to $k_t x_t^{02}$ which can be used to calculate k_t provided that x_t^0 is known. In a glucose molecule, 1 and 2-hydroxyls are in cis-form, while 3-hydroxyl is trans to both 2 and 4. If cis-glycol can be oxidized very rapidly, 2, 3 glycol has very little chance to be attacked before 2-hydroxyl is exhausted in the rapid oxidation. Therefore, trans-glycol can only be contributed by 3 and 4-hydroxyls. The hydroxyl groups in position 4 are always free in a hydrolyzed product. The number of trans-glycols per glucose unit should be equal to the number of free hydroxyl groups in position 3 which is 0.792 as determined by the periodic acid oxidation. From Fig. 2 the slope of the line is 0.024, in which time is expressed in minutes and concentration in number of glycols per glucose units. The specific reaction rate for the oxidation of trans-glycol at 25°C. is equal to 0.0383.

In the first part of the curve, equation (3) should be used and every point in the curve should fit the equation. At one minute, M is equal to 0.564. x_c^0 is found to be 0.730. When those values are substituted in equation (3), k_c is equal to 3.92.

If the secondary and side reactions are negligible, the value of M should reach a maximum which is also the asymptote of the curve. It can be shown that this value is equal to $x_c^0 + x_t^0$. It is quite obvious that both x_c^0 and x_t^0 can be obtained from the rate curve. In other words, the free hydroxyl groups in both positions 2 and 3 can be estimated from one determination.

Free Hydroxyl Groups in Position 2

Two sets of results were obtained:

Time, min.	*1*	*2*	*3*	*4*	*5*
Number of moles of $Pb(OAc)_4$ consumed per glucose unit					
Expt. I	0.5647	0.716	0.8012	0.8313	0.8442
Expt. II	0.563	0.731	0.8065	0.815	0.856

These gave almost the same intercept at 0.730. The methoxyl group in position 2 should be 0.270 per glucose unit.

Free Hydroxyl Groups in Position 3

In the preparation of methyl methyl glucosides, some methyl cellulose remained in the solid state. The methoxyl contents in the hydrolyzed product was 26.15% and the calculated theoretical value is 26.14. This shows that no methoxyl group was removed during hydrolysis and that the hydrolyzed product and the unattacked solid have the same composition.

In periodate oxidation of the methyl methyl glucosides, five determinations gave values from 1.25 to 1.39, averaging 1.31 glycols per glucose unit. The glycol group in methyl cellulose is 1.525 per glucose unit. The increase in glycol groups, due to 3, 4 glycol, is 0.785, which is equal to the free hydroxyl in position 3. The methoxyl group in position 3 should be 0.215 per glucose unit by difference.

GENERAL DISCUSSION ON STRUCTURE OF CELLULOSE XANTHATE

The following discussion is based on the total degree of substitution 0.721 instead of 0.709 since this correction will not change the whole picture to any appreciable extent and since all the determinations were made on methyl cellulose. According to the present results, a cellulose xanthate with a degree of substitution of 0.721 contains 0.243 xanthate groups in position 6, 0.270 in position 2, and 0.215 in position 3. The total xanthate group found is 0.728 instead of 0.721 which is due to experimental errors. The least accurate result is the number of xanthate groups in position 3, because it was obtained from the oxidation of methyl methyl glucosides and methyl cellulose by paraperiodate. It is not surprising that this method gives a result with 3 to 5% error. If the xanthate contains no di and trixanthate, the xanthate group in positions 2 and 3 can also be calculated from the difference between unity and the glycol groups per glucose unit in the methyl cellulose. The xanthate group in position 3 calculated by this method is 0.215 which gives an excellent check on the value of 0.208 calculated from the total degree of substitution. Therefore, 0.208 is a better figure for the xanthate group in position 3. At the same time this gives an indirect confirmation of the distillation result that a normally prepared cellulose xanthate contains no di and trixanthates.

The result shows that the degree of substitution is about the same for the three hydroxyl groups. If the side reactions are assumed to be very slow, the ratio of k_2, k_3, and k_6 is 1.41 : 1 : 1.22. This disproves Lieser's conclusion that cellulose xanthate is exclusively substituted in the position 2, which has also been doubted by others (*25*). At the same time this result indicates that the substitution of one hydroxyl influences the reactivities of its neighbors which is rather contradictory to Spurlin's assumption (*32*). The data are not sufficient at this time to determine whether this result is due to steric hindrances.

SUMMARY AND CONCLUSIONS

1. As derived from the results of the fractionation of cellulose xanthate, the distribution of the xanthate groups among the cellulose chains in a freshly prepared viscose is uneven; however the xanthate groups are more uniformly distributed in a ripened viscose.

2. The xanthate groups can be quantitatively converted into methoxyl groups by methylating the neutral cellulose xanthate with nitrosomethylurethan at 5 to 8°C. for 5 hours. This result confirms those obtained by Lieser et al.

3. The oxidation of glycol groups in methyl glucoses by lead tetraacetate is a second-order reaction and the specific reaction rate of this reation for the cis-glycol is about one hundred times that for the trans-glycol. The specific reaction rate for cis-glycol, k_c, is 3.92 and that for trans-glycol, k_t, is 0.0383.

4. The xanthate groups are approximately uniformly distributed among the three hydroxyls in the glucose anhydride ring. The amount of dixanthate is very small in a normally prepared viscose and trixanthate is nonexistent in the sample.

5. Summary of results on the determination of the structure of cellulose xanthate: average degree of sub-

stitution, 0.721; glycol groups per glucose unit, 0.525; free glucose, 0.279; monoxanthate, 0.721; dixanthate, trace; trixanthate, 0; xanthate groups at position 6, 0.243; xanthate groups at position 2, 0.270; and xanthate groups at position 3, 0.208.

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An Investigation of the Carbohydrate Fraction of Spruce Chlorite Liquors

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In the application of a modified method for the treatment of liquors derived from the sodium chlorite oxidation of sprucewood under conditions suggested for the quantitative isolation of holocellulose, a large alcohol-insoluble fraction, predominantly carbohydrate in nature, has been isolated. On analysis, this fraction yielded large amounts of mannose, galactose, and uronic acids, with smaller quantities of xylose and arabinose. Within the range of experimental cooking conditions, analogous fractions could be isolated from all chlorite liquors, even from oxidations under milder conditions than those previously suggested. It is evident that the use of sodium chlorite for the isolation of holocellulose is not a quantitative method for separation of lignin from carbohydrates; some carbohydrate material is removed before all the lignin is removed from the wood.

For years the efforts of many investigators have been directed toward the separation of the total carbohydrate fraction from the lignin fraction of the wood. The earliest of these was the classical Cross and Bevan method, which consisted of the alternate extraction of the wood with chlorine and sodium sulphite solution. Schmidt and Graumann (*1*) modified this method by substituting chlorine dioxide for chlorine, with subsequent extraction with sodium sulphite solution. Later work by von Euler (*2*) and Heuser (*3*) showed that Schmidt's method removed carbohydrate materials as well as lignin and, thus, could not be considered a method for quantitatively separating the two fractions.

In 1933 Ritter and Kurth (*4*) proposed that wood be treated alternately with chlorine and alcohol-pyridine to remove the lignin and leave the entire polysaccharide fraction of wood; the latter they termed "holocellulose." Later this method was modified by Van Beckum and Ritter (*5*) by substituting monoethanolamine in ethanol as the extracting agent.

Recently, sodium chlorite has been extensively investigated as a delignification agent. Jayme and coworkers (*5–8*) tentatively devised a multistage method for the quantitative separation of lignin from the carbohydrates. Wise and co-workers (*9, 10*) developed a single-stage method for the removal of the lignin and the isolation of the holocellulose.

Jayme and Hanke (*8*) treated sprucewood with aqueous solutions of sodium chlorite and acetic acid in several stages and dialyzed or electrodialyzed the resulting liquors; the latter were subsequently evaporated to dryness, and the residues analyzed *in toto* for methoxyl, carbon, and hydrogen. The respective values for these determinations fell somewhere between the average values for lignin and carbohydrate materials. Hydrolysis of the residues showed the presence of reducing sugars which were tentatively identified as glu-

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cose; in addition, gluconic acid was identified. The total recoverable residues represented a maximum of about 50% of the material lost from the wood during the chlorite oxidation. On the basis of the presence of sugars in liquor that theoretically should contain only lignin, these investigators hypothesized that lignin *in situ* consists of aromatic nuclei with carbohydrate side chains. This explains the presence of excess carbohydrate material (termed *überschuss Polysaccharid*) that is apparent in the isolation of holocellulose; the amount of lignin-free holocellulose (crude holocellulose minus the analytically determined Klason lignin therein) plus the sugars isolated from the liquor is more than the theoretical yield of lignin-free holocellulose—i.e., the weight of the wood minus its Klason lignin content.

Barton (*11*), using the single-stage method of Wise, Murphy, and D'Addieco (*10*) on slash pine, made an extensive investigation of the chlorite liquors. He was able to separate lignin fractions from carbohydrate materials by the conventional dioxane precipitation into ether; the former proved to have a modified lignin structure but gave no evidence of reducing groups. It was concluded that the carbohydrate materials were physically admixed with the lignin in the liquor and could be separated by physical means. In addition, Barton conducted an extensive analysis of the chlorite lignins, establishing tentative unit weights and formulas. The dioxane-insoluble fractions proved to be primarily carbohydrate in nature, yielding mannose and galactose on hydrolysis.

During the present investigation of chlorite liquor from sprucewood, a large alcohol-insoluble fraction, predominantly carbohydrate in nature, was isolated. A fraction of this magnitude has not been reported before; in view of its possible significance for the chlorite process, the material was analyzed and an attempt was made to establish its origin.

WOOD PREPARATION

Thirteen peeled sticks of black spruce (*Picea mariana* B.S.P., average age 40 years) were reduced to a wood meal of 8 to 48 mesh, and extracted with a 2:1 mixture of ethanol-benzene until no further material could be removed. The extraction required 16 days. The unextracted wood contained 4.4% alcohol-benzene soluble material.

COOKING CONDITIONS

The sodium chlorite oxidations, or "cooks," were carried out in one stage, essentially according to the method of Wise, et al. (*10*) for the quantitative isolation of holocellulose; Barton (*11*) adapted the method to large-scale production, and his modification was used in this investigation.

Twenty-eight liters of distilled water were heated in a 35-liter battery jar by indirect and direct steam heat to 75 to 80°C., and 1800 grams (oven-dry basis) of wood meal were added, the mixture being stirred continuously throughout the entire cook. The first addition of 482 grams of sodium chlorite was made, followed immediately by 10 to 20 ml. of acetic acid. A separate investigation proved that the order of addition of the salt and acid was immaterial, provided that the two were added within a few seconds of each other. During the course of the cook, a close check was kept on the acidity of the solution by periodic sampling and determination of the pH by a Beckman meter; sufficient acetic acid was added to maintain the pH at about 4.5. Normally, a total of 120 to 135 ml. of acid was added during the cooks. Sodium chlorite was added after 1, 2, and 3 hours and, after 4.5 hours, the mixture was filtered immediately on a 30-cm. Büchner funnel, and the holocellulose was washed with several portions of distilled water until the odor of chlorine dioxide was no longer evident. The holocellulose was then air dried and analyzed.

TREATMENT OF LIQUOR

The chlorite liquor was concentrated in a large vacuum evaporator (*13*) from 30–35 liters to 3–4 liters and was then electrodialyzed for 48 hours. In this period of time, all chlorite was removed. The purified liquor (about 7 liters in volume) was concentrated *in vacuo* to 1–2 liters and precipitated into 8 volumes of ethanol. The carbohydrate material settled out as a heavy white voluminous precipitate which was filtered, washed with alcohol and ether, and dried *in vacuo*. The lignin in the original liquor was soluble in the alcohol and was recovered by evaporation to dryness, trituration with dioxane, and precipitation of the dehydrated dioxane solution into ether. This method has been described by Brauns (*12*).

Figure 1 is a flowsheet giving the essential details of the liquor treatment. The alcohol-insoluble or carbohydrate fractions from cooks 1–4 are designated as I–IV.

Preliminary analysis showed that the carbohydrate fraction (I) was composed of about 50% reducing sugars (as glucose) determined by the Munson-Walker method. No such large carbohydrate fraction had been reported as being isolated from chlorite liquor, although Barton (*11*) had qualitatively analyzed one of his dioxane-insoluble fractions [25 grams in weight from 1800 grams (oven-dry basis) of slash pine] and had shown the presence of carbohydrate materials. Jayme and Hanke (*8*) had shown that the electrodialyzed residues from their chlorite liquors contained carbohydrates; however, they made no attempt to separate the constituents of these liquors. It was felt that this large carbohydrate fraction would yield information on the mechanism of the chlorite process and might shed some light on the relationship of lignin to carbohydrates in the wood itself.

HOT WATER EXTRACTION OF WOOD

It was thought that part or all of the alcohol-insoluble fraction was material which could be extracted from the wood by hot water. Brauns (*14*) has reported the isolation of a water-soluble polysaccharide from sprucewood, and this material might comprise part or all of the alcohol-insoluble materials isolated in this investigation. A small-scale hot water extraction of the wood was performed under the same conditions as a chlorite cook—i.e., 6% consistency, 75 to 80°C., and 4.5 hours extraction time. No acid or sodium chlorite was added. The resultant solution was concentrated and precipitated into alcohol; the dried precipitate amounted to nearly 1% of the original wood.

A large-scale extraction gave similar results. Chlorite cook 2 was performed on this water-extracted wood,

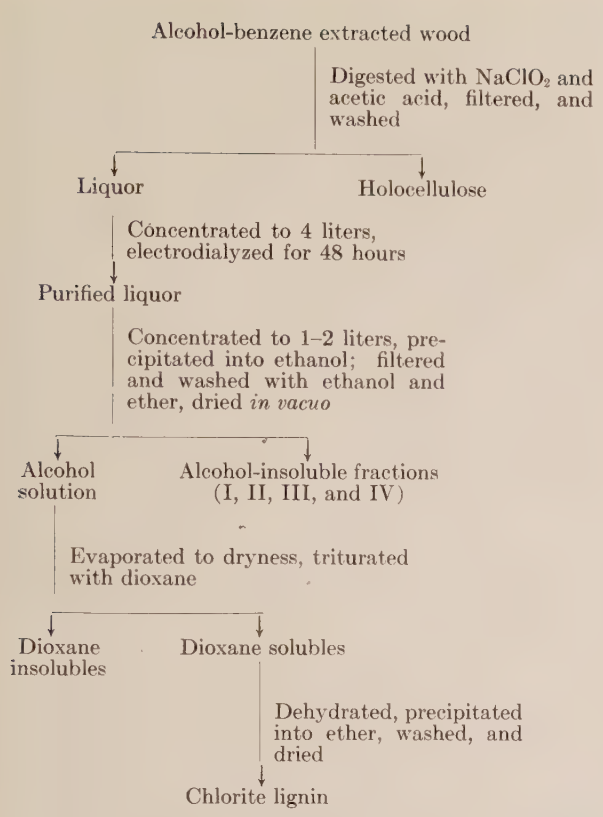
Alcohol-benzene extracted wood
Digested with $NaClO_2$ and acetic acid, filtered, and washed
Liquor
Holocellulose
Concentrated to 4 liters, electrodialyzed for 48 hours
Purified liquor
Concentrated to 1–2 liters, precipitated into ethanol; filtered and washed with ethanol and ether, dried *in vacuo*
Alcohol solution
Alcohol-insoluble fractions (I, II, III, and IV)
Evaporated to dryness, triturated with dioxane
Dioxane insolubles
Dioxane solubles
Dehydrated, precipitated into ether, washed, and dried
Chlorite lignin

Fig. 1. Flowsheet of treatment of chloride liquor

using the conditions of cook 1. The liquor was treated in the usual manner but, during the electrodialysis process, a portion of the liquor was lost. The remainder was purified by dialysis, and the alcohol-insoluble fraction (II) was precipitated in the usual manner. The yield of this fraction was 100 grams. This experiment proved that the major portion of the carbohydrate fractions could not result from the hot water-soluble materials in sprucewood.

Several possibilities existed for the origin of the alcohol-insoluble fractions; the most plausible was that the cooking conditions were too drastic and that some of the true holocellulose material was removed simultaneously with the lignin. Wise, et al. (*10*) has stated that the Klason lignin content of the holocellulose should not be allowed to fall below 2 to 4% (the exact figure being dependent on the type of wood); with a lower lignin content, considerable degradation of the holocellulose takes place. The Klason lignin contents of the holocelluloses of cooks 1 and 2 were 1.6 and 1.8%, respectively. By this criterion, then, the cooking conditions were too drastic; in the following cooks, milder conditions were employed.

COOKS 3 AND 4

In cook 3, 560 grams of sodium chlorite were added hourly instead of the usual 482 grams, but only three such additions were made and the cooking time was three hours. The treatment of the liquor was similar to that of the liquors of cooks 1 and 2, and 100 grams of alcohol-insoluble material were isolated (III). The Klason lignin content of the holocellulose was 3.1%.

In cook 4, it was desired to produce a holocellulose with a Klason lignin content above 4%. The time was 3 hours and three additions of 450 grams of sodium chlorite were made. The liquor was treated in the usual manner, and 102 grams of alcohol-insoluble material were isolated. The Klason lignin content of the holocellulose was 5.9%.

These last cooks prove conclusively that, under cooking conditions mild enough to leave more lignin in the holocellulose than was previously deemed necessary, alcohol-insoluble fractions could be isolated from the liquors in appreciable quantities. The yields of "lignin-free" holocellulose (yields of crude holocellulose corrected for the Klason lignin content) of these cooks varied from 74 to 80%, whereas the theoretical yield was 72.1%. Thus, chlorite oxidation under conditions mild enough to produce yields of holocellulose greater than theoretical and with Klason lignin contents higher than commonly deemed necessary removed alcohol-insoluble materials from the wood.

INVESTIGATION OF CARBOHYDRATE FRACTIONS

Principal attention was devoted to the carbohydrate fraction of cook 1 (I). The methoxyl content was 3.04%*; after precipitation from an aqueous solution into ethanol, the methoxyl content was 2.95%. Samples of the material were exhaustively extracted in Soxhlet extractors with anhydrous dioxane and absolute alcohol. Neither solvent removed more than traces of material, and the methoxyl contents of the extracted substances were the same as formerly—namely, 2.90 and 2.75% for the alcohol- and dioxane-extracted material, respectively.

Time Hydrolysis Curves

In order to establish the amount of reducing sugars that was present in the carbohydrate fractions, rate of hydrolysis curves were determined. Two grams of the materials were dissolved in exactly 150 ml. of 2% sulphuric acid and the mixtures were refluxed in a glycerin bath (120°C.). Zero time was calculated from the commencement of boiling; periodically, samples were withdrawn, neutralized with sodium bicarbonate, cooled, filtered, and 10 ml. were removed by pipet for analysis by the Munson-Walker method (*15*). The curves for I, III, and IV are given in Fig. 2.

The materials give basically similar curves, although the absolute amount of reducing sugars determined varied rather widely. The more drastic the cooking conditions, the more reducing sugars were present in the carbohydrate fractions. This indicates that the origin of these fractions is in the holocellulose itself, and that carbohydrate materials are removed therefrom well before the theoretical holocellulose stage is reached.

Mannose

Barton (*11*) reported the presence of mannose in one of his dioxane-insoluble fractions; in order to determine whether it was present in these carbohydrate fractions, a simultaneous qualitative and quantitative test for mannose was carried out according to the method of Wise, Ratliff, and Browning (*16*), consisting of the isolation of mannose phenylhydrazone. Qualitatively, a precipitate of mannose phenylhydrazone was obtained from I with a melting point of 195°C. (on the Fisher-Johns melting point block) after two recrystallizations from 95% ethanol. The reported melting point is

* All samples for methoxyl determination that had come in contact with alcohol were evaporated to dryness from an aqueous solution. This removed the last traces of alcohol.

199–200°C. This established the presence of mannan in I; quantitatively, this material analyzed 18% mannan.

Galactose

The presence of galactose in I was established by the oxidation of the material with nitric acid; a good crop of crystals of mucic acid was obtained by this method. The melting point after one recrystallization from water was 211–212°C.; the reported melting point is 212–215°C.

Galacturonic Acid

A naphthoresorcinol test having established the presence of uronic acids in I, a Heidelberger-Goebels test for galacturonic acid was performed to determine if this substance comprised part of the acids. In essence, this consists of the oxidation of galacturonic acid to mucic acid by bromine and hydrobromic acid. Since no mucic acid was formed, it was concluded that galacturonic acid was not present in I.

Paper Chromatography

Further identification of the reducing sugars in I was made by the paper chromatography method of Partridge (*21*). The results showed the presence of large amounts of mannose and galactose, and smaller amounts of xylose. Arabinose could not be identified by this method, inasmuch as arabinose and mannose occupy nearly identical positions on the paper strip. Large quantities of mannose tend to obliterate any spot caused by arabinose, making a visual separation impossible. No glucose could be identified, in contrast to the results of Jayme and Hanke (*8*), who reported that the sugars in the residues of the chlorite liquor were predominantly glucose.

Differential Fermentation

In order to determine the quantities of the various sugars present in the carbohydrate fractions, the microbiological differential fermentation method of Wise and co-workers (*22–24*) and Auernheimer, Wickerham, and Schniepp (*25*) was applied. Three such sugars may be directly determined by this method—D-galactose, D-xylose, and L-arabinose. However, knowing that glucose was absent and that mannose and galactose were the only hexoses present, the amount of mannose could be determined by difference. Similarly, the amount of uronic anhydride existing as free acids could be determined; these acids are not fermented appreciably by any of the yeasts, and the residual Munson-Walker reducing value after all known sugars had been fermented was assumed to represent uronic acids.

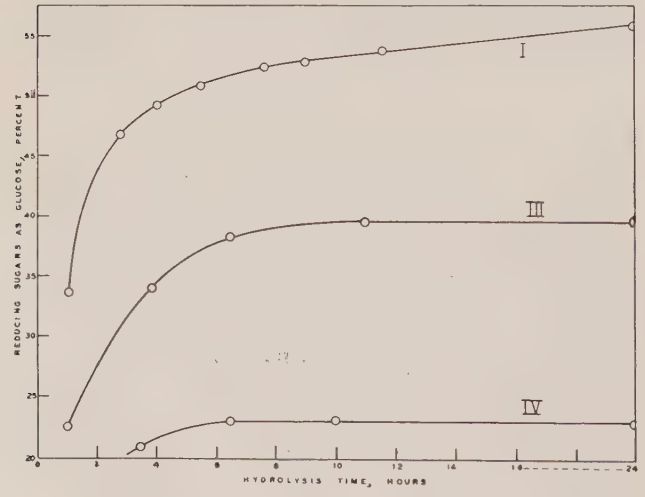

Fig. 2. Time hydrolysis curves I, III, and IV

Two carbohydrate fractions were analyzed (I and IV). These represented materials prepared under the severest and mildest cooking conditions, respectively. The results are given in Table I.

These results indicate that the major portion of the reducing sugars consists of mannose and galactose, with smaller amounts of pentoses. The amount of mannan in I compares well with the yield of that substance obtained gravimetrically—18%. This is further evidence that glucose is absent, and justification for the assumption that fermentation of the hexoses involves only mannose and galactose. That arabinose is present in IV is somewhat surprising, in view of the fact that hot water-extracted wood was used for this cook; hot water is known to remove arabinose-containing material. However, the extraction in this work was not exhaustive.

A portion of the hydrolyzate from which the hexose sugars had been removed by fermentation was chromatographed. This confirmed the presence of both arabinose and xylose; previously, arabinose has not been identified by this method because of the presence of mannose. With the removal of the latter, the spot caused by arabinose was clearly evident.

With the exception of xylose, the different sugars were present in about proportionately equal amounts in I and IV. The small quantity of xylose in IV suggests that the sugar is removed from wood only as a result of the more drastic cooking conditions of cook 1.

Investigation of Hydrolysis Residues

During the acid hydrolysis of all the carbohydrate fractions, a brown, acid-insoluble residue was formed which exhibited some of the physical characteristics of lignin materials. These residues amounted to 2.0% for I and 18.8% for IV. The methoxyl contents were 9.5% and the ultraviolet absorption curves resembled those of lignin derivatives. It is thus quite probable that these residues were ligninlike in nature.

Analysis of Water-Soluble Extract

The hot water extract of sprucewood which was removed prior to cooks 2, 3, and 4 had a reducing sugar content of 92% (calculated as galactose). A chromatographic analysis indicated the presence of only arabinose

Table I. Differential Fermentation Results

	Fraction		
	I, %	*IV*, %	Ratio *I*/*IV*
Munson-Walker reducing value of original hydrolyzate (as glucose)	53.3	22.5	2.4
Mannan[a]	17.7	7.1	2.5
Galactan	16.4	6.4	2.6
Xylan	2.0	0.3[b]	6.7[b]
Araban	3.2	1.4	2.3
Uronic anhydride[c]	9.0	5.1	1.8
Total	48.3	20.3	2.4

[a] Calculated by assuming that the hexoses present are composed entirely of mannose and galactose.
[b] These are questionable values; only traces of xylose were found in IV.
[c] Calculated by assuming that all residual reducing value after fermentation of hexoses and pentoses is due to uronic acids.

and galactose; this is in good agreement with the results of Brauns (*14*).

Balance of Alcohol-Insoluble Fractions

Summative analyses of I and IV, which included reducing polysaccharides, acid-insoluble residues, net uronic anhydride, and ash, indicated that approximately 65% of these materials could be accounted for. The remaining 35% was not readily identifiable; the possibility existed that it could be either carbohydrate or lignin in nature. For various reasons—such as the low carbon content of I (40%) and the low methoxyl contents (corrected for known methoxyl of the acid-insoluble residues in these materials) of I and IV (2.7 and 3.2%, and respectively)—it was concluded that the unknown portion of these materials was carbohydrate in nature. Jeanes and Isbell (*26*) have indicated that reducing sugars are oxidized by sodium chlorite solutions to aldonic acids. Jayme and Hanke (*8*) reported the identification of aldonic acids in the chlorite liquors. Such acids would be nonreducing and could account for the 35% of the carbohydrate fractions not identified.

The two materials (I and IV) were titrated conductimetrically to determine the amount of carboxyl material present. An excess of standard alkali was added to the materials and the solutions were titrated with standard acid. Calculations from these experiments showed the presence of 9.68 and 15.25% carboxyl material (calculated as carbon dioxide) in I and IV, respectively. Correcting these figures for the respective acid-insoluble residues (assuming that the latter contain two hydroxyl and two carboxyl groups—per unit weight of 600—that are capable of titration†) and for the analytically determined uronic acids (calculated as carbon dioxide), the net carbon dioxide contents of these fractions are 4.6 and 5.8%, respectively; calculated to aldonic anhydride, they are 18.4 and 23.2%, respectively. Regardless of the exact nature of the materials, it is evident that considerably more carboxyl material is present than may be accounted for by uronic acids and lignin degradation products.

SUMMARY OF COOKS

The analysis of the original sprucewood is given in Table II.

The analyses of the principal products of the cooks are listed in Table III; the summations of the constituents of the carbohydrate fractions, I and IV, are given in Table IV.

The theoretical yield of lignin-free holocellulose from sprucewood is 72.1%; only in cook 1 is this figure approached. In all others, the yields are higher—especially in cooks 3 and 4, where the cooking conditions were milder. In spite of the high yields of lignin-free holocellulose, in each case 100 grams or more of alcohol-insoluble material have been isolated from the chlorite liquor. This is further evidence of the fallacy of correcting holocellulose yields for the Klason lignin content therein; this theory has been expounded by Jayme and Finck (*27*).

Table II. Analysis of Sprucewood

	%
Methoxyl	5.07
Ash	0.10
Klason lignin	27.9
Uronic anhydride	4.00
Apparent pentosans	12.8
Corrected pentosans	10.7
Theoretical yield of holocellulose	72.1

† The assumption is made that these acid-insoluble residues are similar to chlorite lignin as analyzed by Barton (*11*).

CHLORITE OXIDATION OF INDULIN

One of the possibilities for the origin of the carbohydrate fractions lay in the oxidation of the lignin itself. If lignin is formed in the living tree by reduction of the carbohydrate materials, as has been frequently suggested (*28*), then conceivably the process could be reversed and carbohydrate materials might be produced from lignin by oxidation. To test this hypothesis, Idulin "A," an isolated kraft lignin product of the West Virginia Pulp and Paper Co., was subjected to a chlorite oxidation.

The Indulin was oxidized in lots of 15 grams, using 45 grams of sodium chlorite in 2 liters of water, according to the method suggested by Barton (*11*). Seven such cooks were made; the resultant liquors were combined and treated in a manner analogous to that for spruce chlorite liquor (Fig. 1). An alcohol-insoluble fraction of 12 grams was obtained; hydrolysis of this material showed that no reducing sugars were present that could not be accounted for by hydrolysis of the original Indulin [presumably caused by small amounts of contaminating carbohydrate materials (about 0.8% of the Indulin)]. However, the yield of this alcohol-insoluble fraction was quite similar to the yields of the nonreducing portions of the alcohol-insoluble fractions, I and IV (the yields in all cases being computed on the Klason lignin contents of the original source materials—Indulin and sprucewood, respectively).

From these experiments, it was concluded that reducing carbohydrate materials were not formed from Indulin by chlorite oxidation under the conditions employed, whereas it was conceivable that some nonreducing carbohydrates could be formed. However, since Indulin is a condensed lignin that has undergone rather drastic treatment in the process of isolation, it is

Table III. Summary of Cooks and Products[a]

	Cooks			
	1	*2*	*3*	*4*
Weight of wood, g.	1800	1800[b]	1800[b]	1800[b]
Length of cook, hr.	4.5	4.5	3.0	3.0
$NaClO_2$ added (based on wood), %	107	107	93	75
Klason lignin in holocellulose, %	1.60	1.84	3.10	5.90
Yield lignin-free holocellulose (based on wood), %	73.6	75.7	81.6	84.7
Uronic anhydride, holocellulose, %	6.2	..	6.5	7.0
Corrected pentosans, holocellulose, %	10.6	..	11.0	10.6
Yield carbohydrate fraction (based on wood), %	7.9	5.5	5.5	6.0
Yield-reducing sugars (based on carbohydrate fraction), %	56.2	50.0	34.0	23.0
Yield-reducing sugars (based on wood), %	4.4	2.8	1.9	1.4
Uronic anhydride, carbohydrate fraction, %	17.6	17.4	19.4	17.6
Pentosans, carbohydrate fraction, %	8.6	9.7	6.9	4.0
Corrected pentosans, carbohydrate fraction, %	4.2	4.0	. 0	1.7[c]
Theoretical aldonic acids, carbohydrate fractions, %	18.4	..	..	23.2

[a] All figures on oven-dry basis.
[b] Hot water-extracted wood.
[c] Differential fermentation results.

possible that other lignin products—such as native lignin—might be more amenable to chlorite oxidation.

DISCUSSION

This investigation has revealed the presence of hitherto unsuspected quantities of carbohydrate materials in the chlorite liquors of sprucewood. The isolation of these fractions depended on the development of a method of liquor treatment different from those of Barton (*11*) and Jayme and Hanke (*8*). The yields of reducing sugars in these fractions were a function of the cooking conditions—with the more drastic conditions, more reducing sugars were isolated from the liquor (the Klason lignin content of the residual holocellulose was also less). However, even under conditions that produced yields of holocellulose well above the theoretical, appreciable amounts of such alcohol-insoluble materials were isolated.

In view of these results, some of the previous concepts of the sodium chlorite process for the production of holocellulose must be revised. The idea that only lignin is removed during such an oxidation is erroneous, and it seems evident that some carbohydrate material is removed from the wood well before the theoretical holocellulose stage is reached. The evidence seems to indicate that this material is removed simultaneously with the lignin; this may occur during the earliest stages of the process. In any case, by the time the residual Klason lignin content of the holocellulose is 6%, some carbohydrate material has gone into solution.

This tends to support the views of other investigators that the earlier concepts of the quantitative nature of the chlorite process were erroneous; the fact that the summations previously calculated have added up to 100% of the wood has been purely fortuitous. In addition, the results of cooks 3 and 4 indicate the fallacy of correcting the yields of crude holocellulose for the Klason lignin therein; this was earlier expounded by Jayme and Finck (*27*).

It seems probable that part of the alcohol-insoluble, water-soluble material may consist of a lignin-carbohydrate complex. The lignin material is not removed by solvent extraction but may be isolated by acid hydrolysis. With milder cooking conditions, the lignin content of the carbohydrate fraction increases. Evidently some hydrolysis of this lignin-carbohydrate complex takes place after the material has been removed from the wood. This supports the idea that the carbohydrates are removed from the wood with the lignin in the earlier stages of the cook.

The origin of these carbohydrate materials is unknown at present. The possibility that they are produced by chlorite oxidation of lignin must be discarded. The presence of mannan suggests that some true cellulosan material has been removed from the wood; mannan is considered to be one of the cellulosan materials. Xylan although likewise considered a cellulosan, may also be derived from the polyuronide hemicelluloses.

Table IV. Summation of I and IV

	I, %	*IV*, %
Reducing sugars	48.3	20.3
Net uronic anhydride[a]	8.6	12.5
Acid-insoluble residue	4.6	18.8
Calculated aldonic acids	18.4	23.2
Ash	6.8	12.3
Total	86.7	87.1

[a] Difference between gravimetrically determined uronic anhydride and uronic anhydride determined by differential fermentation (see Table I).

The presence of large amounts of uronic acids in the fractions, the fact that these fractions seem to be removed simultaneously with the lignin, and the evidence that a lignin-carbohydrate complex exists in these fractions strongly indicate that the alcohol-insoluble materials have their origin in the incrusting polyuronides of the wood. Norman (*29*) has given abundant evidence that lignin removal is difficult without the corresponding removal of some polyuronide hemicellulosic material, and vice versa. It is commonly accepted that the two are, in part at least, chemically combined with one another. Consequently, it is not surprising that lignin and polyuronide hemicelluloses should be removed from the wood simultaneously and be recovered from the chlorite liquor.

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ASSOCIATION NEWS AND EVENTS

Alkaline Pulping Conference

The TAPPI Alkaline Pulping Conference will be held at the John Marshall Hotel, Richmond, Va., on Sept. 26–28, 1951. Henry Vranian of The Chesapeake Corp. of Va., West Point, Va., is general chairman and R. R. Fuller of the Gulf States Paper Co., Tuscaloosa, Ala., is program chairman. Following is the final program:

Meeting of Wednesday, September 26

9:30 a.m. Wood Room Operation Session (Virginia Room) *Henry Vranian, Chairman*

1. "The Cellulosic Raw Materials Situation," by James W. Cruickshank, U. S. Forest Service, Asheville, N. C.
2. "Checking Wood Quality," by M. Klein and J. M. Ralson, Union Bag & Paper Corp., Savannah, Ga.
3. "Chipping Operations," by Vance P. Edwardes, Consultant, Corinth, N. Y.
4. "Effect of Chipping Knife on Wood Conservation," by Harold F. Wood, Jr., Heppenstall Co., Pittsburgh, Pa.
5. "Usable Wastes in the Woods," by J. J. Armstrong, Union Bag & Paper Corp., Savannah, Ga.
6. "Wood Losses in Chipper Operation," by N. P. Wardwell, Carthage Machine Co., Carthage, N. Y.

12:30 p.m. Luncheon (Roof Garden)

2:00 p.m. Wood Room Operation Session Continued (Virginia Room)

7. "Suspension Burning of Bark Refuse," by Robert E. Ellwanger, Cheaspeake Corp. of Va., West Point, Va.
8. Color film: "Bark Furnace in Operation," by Otto de Lorenzi, Combustion Engineering-Superheater, Inc., New York, N. Y.
9. "Survey of Chipping Operations," by R. H. Stevens, National Container Corp., Jacksonville, Fla.
10. Discussion of papers on Wood Room Operation.
11. "Coating Ingredients from Tall Oil," by C. R. Outterson and M. G. Selden, Albemarle Paper Mfg. Co., Richmond, Va., and J. W. Eldridge, Asst. Prof., Chemical Engineering, University of Virgina, Charlottesville, Va.
12. "Flash Drying of Lime Kiln Mud," by Henry Vranian, Chesapeake Corp. of Va., and Robert D. Nickerson, Combustion Engineering-Superheater, Inc.

Meeting of Thursday, September 27

9:30 a.m. Cooking Symposium (Virginia Room) *R. R. Fuller, Chairman*

1. "Cooking Knots and Rejects," by K. G. Chesley, Crossett Lumber Co., Crossett, Ark.
2. "Discussion of Controls, Circulation, and Indirect Heaters," by Robert Bowen, North Carolina Pulp Co., Plymouth, N. C.
3. "Effect of Bark in Sulphate Pulping of Slash Pine," by J. S. Martin and K. J. Brown, Forest Products Laboratory, Madison, Wis.
4. "Continuous Manufacture of Semichemical Pulp for Corrugating Board," by J. McK. Limerick, Bathurst Power & Paper Co., Bathurst, N. B.
5. "Quality of Paper from the Sutherland High Yield Sulphate System," by Douglas G. Sutherland, Sutherland Refiner Corp., Trenton, N. J.
6. "Chemical Reaction Equilibria in the Combustion of Sodium-Base Pulping Liquors," by Malcolm N. May, Institute of Paper Chemistry, Appleton, Wis.
7. "Cooking Southern Wood for High Brightness Bleached Sulphate Pulp," by Malcolm B. Pineo, Brunswick Pulp & Paper Co., Brunswick, Ga.

12:30 p.m. Luncheon (Roof Garden)

2:00 p.m. Cooking Symposium Continued (Virginia Room)

8. "Neutral Sulphite Semichemical Pulp," by Richard G. Coker, Sonoco Products Co., Hartsville, S. C.
9. "Semichemical Pulping and Wood Species," by J. N. McGovern and E. L. Keller, Forest Products Laboratory, Madison, Wis.
10. "Scandinavian Pulping Practices" (Speaker to be announced).
11. "Review of Methods of Determining Degree of Pulping."
12. "The Kamyr Continuous Digester," by Johan Richter, Karlstadt Machine Works, Karlstadt, Sweden.
13. "Distribution of Cellulose and Hemicellulose in the Cell Wall of Sulphate Pulp in Comparison with Other Pulps," by Paul Lange, Swedish Forest Products Research Inst., Stockholm, Sweden.
14. Panel Discussion on Cooking: R. R. Fuller, Moderator.
    "Hard Cooking of Northern Woods," by John P. Lunderville, Brompton Pulp & Paper Co., Red Rock, Ont.
    "Equipment," by A. C. Clarke, Emerson Mfg. Co., Lawrence, Mass.; T. W. Small, Sprout, Waldron & Co., Muncy, Pa.; L. D. Smiley, Gruendler Crusher & Pulverizer Co., St. Louis, Mo.; and L. S. Durant, Paper & Industrial Appliances, Inc., New York, N. Y.
    "Cooking for Bleached Pulp," by W. A. Stone, Mathieson Chemical Corp., Baltimore, Md.
    "Corrosion" (Panel member to be announced).
    "Instrumentation," by J. M. McAlear, Mason-Neilan Regulator Co., Boston, Mass.
    "Operation," by Franklin L. Jones, St. Joe Paper Co., Port St. Joe, Fla.; W. F. Gillespie, Gaylord Container Co., Bogalusa, La.; others to be announced.

Program of Friday, September 28

1. Visit to the mill of the Chesapeake Corp. of Va., at West Point, Va.
2. Luncheon and Visit to the Colonial Village, Williamsburg, Va.
3. Return to Richmond, Va.

International Pulp and Paper Symposium

The entire month of September is a gala month for chemists. During this period the American Chemical Society celebrates its Diamond Jubilee in New York and Washington. At the same time the National Research Council sponsors the World Chemical Congress in the same cities. A feature of these meetings is the presence of a large number of foreign scientists, many of whom are outstanding in the field of cellulose chemistry.

To benefit by their presence in this Country arrangements have been made to have several of these scientists attend a group of meetings in Appleton, Wis.

On Sept. 17–18 there will be open technical sessions of the Wood Chemistry Committee of the Food and Agriculture Organization at The Institute of Paper Chemistry.

The program of the Wood Chemistry Committee on Sept. 17–18 is followed by The Institute of Paper Chemistry and TAPPI Fundamental Research Committee's sponsored International Pulp and Paper Symposium on Sept. 19–20. On Sept. 21 the Institute will hold its Round Table Meeting on Cellulose, Lignin, Pulp, and Paper.

Following is the program of the International Pulp and Paper Symposium, sponsored by The Institute of Paper Chemistry, the UNFAO, and the TAPPI Fundamental Research Committee.

September 16—3:00 p.m.

Hotel Conway

Closed meeting of the Wood Chemistry Subcommittee, FAO

September 17—9:00 a.m.

The Institute of Paper Chemistry

Open technical sessions of the Wood Chemistry Subcommittee, FAO

Introductory Remarks by Herman Mark, Committee Chairman, and Harry F. Lewis, in charge of program arrangements

TROPICAL WOODS AS A SOURCE OF PULP

Chairman W. G. Campbell, Forest Products Research Laboratory, Princes Risborough, England

1. "Species Sampling on a Reproducible Basis," by W. E. Cohen, Commonwealth Scientific and Industrial Research Organization, South Melbourne, Australia.
2. "Tropical Wood Distribution and Forestry Practice," by Robert W. Hess, formerly Yale School of Forestry, now The Mengel Co., Louisville, Ky.
3. "The Physical Characteristics of Tropical Woods," by Frederick Wangaard, Yale School of Forestry, New Haven, Conn.
4. "The Chemical Characteristics of Tropical Woods," by Louis E. Wise, The Institute of Paper Chemistry, Appleton, Wis.
5. "Morphology and Fiber Measurements of Tropical Wood Fibers," by Irving H. Isenberg, The Institute of Paper Chemistry.
6. Discussion of the value of laboratory data on the screening of tropical woods.

September 17—1:30 p.m.

The Institute of Paper Chemistry

TROPICAL WOODS AS A SOURCE OF PULP (contd.)

Chairman J. Albert Hall, Director, U. S. Forest Products Laboratory, Madison, Wis.

7. "Pulping Studies with the Tropical Woods of Brazil," by L. Rys, Industrias Klabin do Parana de Cellulose, Brazil.
8. "Pulping Studies with African Tropical Woods," by R. Peteri, Chief, Research Dept.; Régie Industrielle de la Cellulose Coloniale, Paris, France.
9. "Pulping Studies with Colonial Tropical Hardwoods as Papermaking Materials" by H. E. Coomber, Colonial Products Advisory Bureau (Plant and Animal), South Kensington, England.
10. "Viscose Rayon Pulps from Chilean Coigue, Tepa, and Ulmo," by F. A. Simmonds and R. M. Kingsbury. Forest Products Laboratory, Madison, Wis.
11. "Development of Chemical and Semichemical Pulping Processes from Tropical Hardwoods from West Africa," by Roland O. H. Runkel, Federal Institute for Forest and Wood Research, Reinbek, Germany.
12. "Chemical Pulps from Australian Eucalyptus," by A. Meller, Australian Paper Manufacturers Ltd., South Melbourne, Australia.
13. "Chemical Utilization of Tropical Hardwoods," by W. G. Campbell.
14. Summary of papers 7–13, by John N. McGovern, Forest Products Laboratory, Madison, Wis.

September 18—9:00 a.m.

The Institute of Paper Chemistry

THE CHEMICAL UTILIZATION OF AGRICULTURAL RESIDUES

Chairman J. E. Atchison, Pulp & Paper Branch, Economics Cooperation Administration, Washington, D. C.

15. "Characteristics of Pulp Fibers from Agricultural Residues," by E. C. Lathrop, U. S. Dept. of Agriculture, Northern Regional Research Laboratory, Peoria, Ill.
16. "Cereal Straw Pulping in Great Britain" by L. G. S. Hebbs, Cross & Bevan, Bedfordshire, England.
17. "The Developments in Straw Pulping in The Netherlands," by F. M. Muller, Netherlands Proefstation Voor Stroverwerking, Groningen, The Netherlands.
18. "Recent Developments in the Pulping of Straw in the United States," by S. I. Aronovsky, U. S. Dept. of Agriculture, Northern Regional Research Laboratory, Peoria, Ill.
19. "Modern Industrial Pulping of Straw and Bagasse," by Alexander Kasser, Parsons and Whittemore, Inc., New York, N. Y.
20. Discussion of papers 15–19, by J. E. Atchison and W. O. Hisey, Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

September 18—1:30 p.m.

The Institute of Paper Chemistry

Chairman Herman Mark, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

21. General discussion of the possibility of establishing FAO standard methods in the field of wood chemistry and pulp and paper, under the leadership of R. G. Macdonald, Secretary of the Technical Association of the Pulp and Paper Industry, New York, N. Y.
22. "Report on the Determination of Lignin," by W. E. Cohen.
23. "Progress Report on the Technical Assistance Program of the FAO," by E. Moerath, Food and Agriculture Organization of the United Nations, Rome, Italy.
24. Open discussion on the past, present, and possible future program of the Wood Chemistry Subcommittee, FAO, under the leadership of Herman Mark.

Guided tours of the laboratories and other facilities of The Institute of Paper Chemistry at the close of the Tuesday afternoon session. The laboratories and library are open for informal visits throughout the week.

September 18—8:00 p.m.

Closed business meeting of the Wood Chemistry Subcommittee, FAO

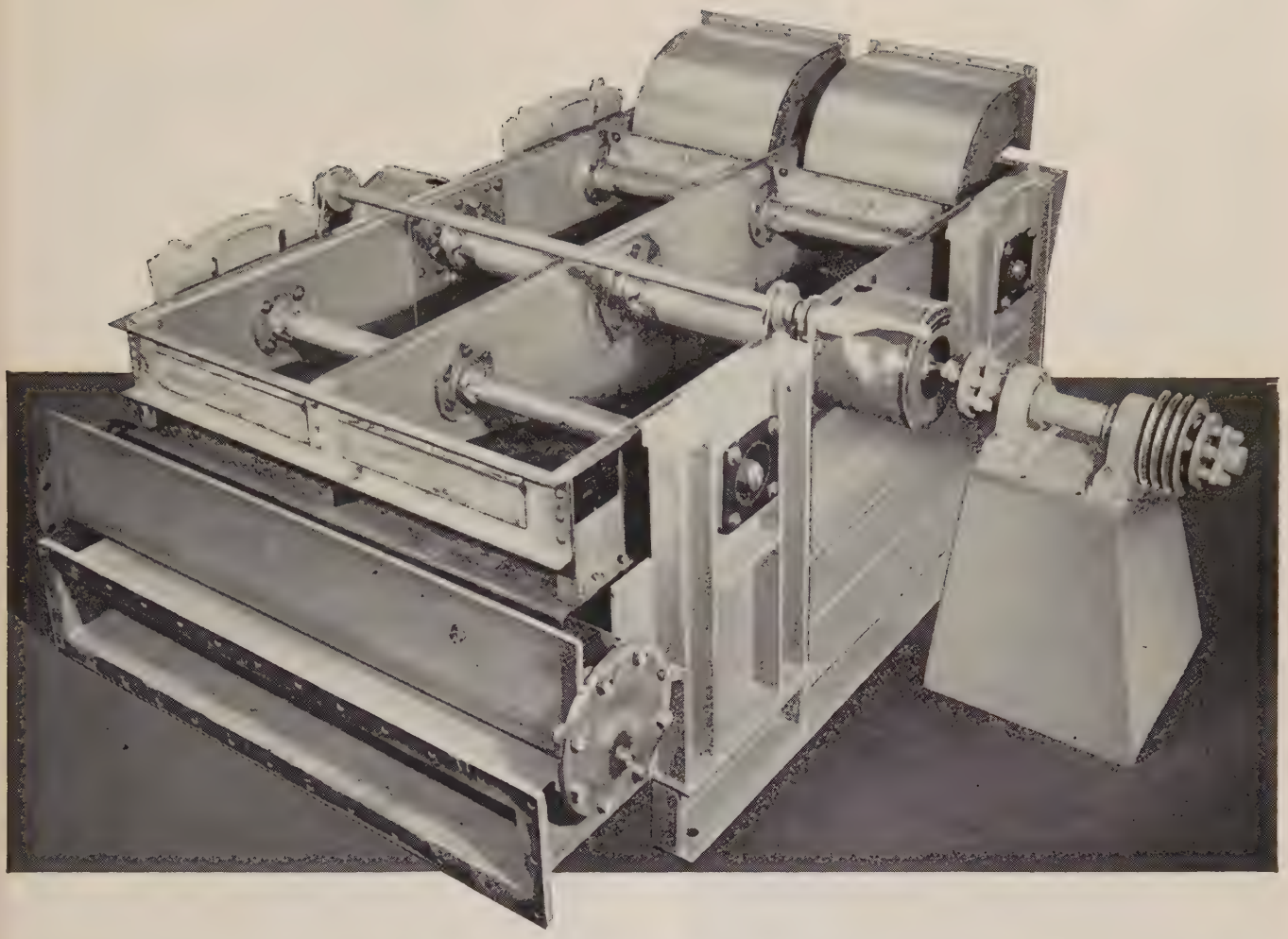
September 19—9:00 a.m.

The Institute of Paper Chemistry

OPEN TECHNICAL SESSIONS OF THE PULP AND PAPER SYMPOSIUM

Chairman Clifford B. Purves, McGill University, Montreal, Canada

25. "The Cause of the Reddening of Pulps and Its Technical



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Significance," by E. Adler, Swedish Forest Products Research Laboratory, Stockholm, Sweden.

26. "Dynamic Measurements of the Physical Properties of Pulp and Paper by Audio-Frequency," by Masao Horio, Kyoto University, Kyoto, Japan.
27. "The Formation of Lignin in Wood and Its Removal During Pulping," by K. Freudenberg, University of Heidelberg, Heidelberg, Germany.
28. "The Chemical Composition of Fiber Fractions from Nonbeaten and Beaten Fiber Materials," by Öyvind Bryde, Vestfos Cellulosefabrik, Vestfossen, Norway.
29. "The Cause of Foaming of Green Groundwood," by John W. Green, The Institute of Paper Chemistry.

September 19—1:30 p.m.

The Institute of Paper Chemistry

30. Panel Discussion: WHAT SHALL WE DO WITH SPENT SULPHITE LIQUOR? Moderator, Harry F. Lewis. Panel Members: Öyvind Bryde, Vestfos Cellulosefabrik; Heinz Haas, Zellstofffabrik Waldhof; William Herriott, Kimberly-Clark Corp.; Jesse M. Holderby, Lake

Groups visiting the Brown Co., Berlin, N. H., during the Maine-New Hampshire Section Meeting, June 22–23, 1951

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September 19—6:30 p.m.

Riverview Country Club

Complimentary dinner (informal) honoring the foreign guests. All members of the Symposium are invited. Reservations must be in by noon, Sept. 17

September 20—9:00 a.m.

The Institute of Paper Chemistry

Chairman Emil Heuser, The Institute of Paper Chemistry, Emeritus, La Jolla, Calif.

31. "The Isolation and Identification of the Sugars Present in the Hemicelluloses of Wood or Pulp," by J. K. N. Jones, University of Bristol, Bristol, England.
32. "The Distribution of Cellulose and Hemicellulose in the Cell Wall of Sulphite and Sulphate Pulps," by Paul W. Lange, Swedish Forest Products Research Laboratory, Stockholm, Sweden.
33. "The Characteristics of a Wood Pulp for Viscose Manufacture," by Heinz Haas. (Discussion of this paper to be led by Leif Jörgensen and Masao Horio.)
34. "Hot Alkali Stability and Acid Hydrolytic Resistance of Modified Cellulose," by A. Meller.
35. "A Report on Certain Recent Researches of Technical Interest in the Swedish Forest Products Research Laboratory," by E. Hägglund, Swedish Forest Products Research Laboratory, Stockholm, Sweden.

September 20—1:30 p.m.

The Institute of Paper Chemistry

36. Panel Discussion: Pilot Planting for the Paper Industry. Moderator, Roy P. Whitney, The Institute of Paper Chemistry. Panel Members: Karl Adamik, Institute of Wood Chemistry, Graz, Austria; G. H. Chidester, U. S. Forest Products Laboratory, Rodger M. Dorland, Abitibi Power & Paper Co., Ltd.; John S. Hart, Pulp and Paper Research Institute of Canada; Walter F. Holzer, Crown Zellerbach Corp.; D. J. MacLaurin, The Institute of Paper Chemistry; Börje Steenberg, Swedish Forest Products Research Laboratory.

September 20—6:30 p.m.

Dinner meeting of the Lake States Section of TAPPI complimentary to the foreign members of the Pulp and Paper Symposium. Tickets should be purchased at the Hotel Conway.

Speaker: Börje Steenberg, Director of Research, Paper Technology Dept., Swedish Forest Products Research Laboratory, Stockholm, Sweden

Subject: "The Formation of the Sheet and the Behavior of Stock on the Wire"

September 21

The Institute of Paper Chemistry

Three Informal Round Tables:

1. Lignin.
2. Cellulose and the Hemicelluloses.
3. Pulp and Paper.

While the above sessions will be largely informal, there will be one or two papers in each session to set off discussion. In the Lignin Session, for example, W. G. Campbell will describe his work on Acid-Soluble Lignin. In the Cellulose and Hemicellulose Round Table, G. F. Davidson of the Shirley Institute will cover the subject "The Oxidation of Aldehyde Groups in Oxycellulose" and M. Horio, "Physicochemical Studies on Xylan—Size and Shape by Light Scattering, X-Ray Analysis and Birefringence." One of the subjects requested for discussion at the Pulp and Paper Round Table is that of pulp evaluation.

Research Appropriations Committee

W. H. Swanson of the Kimberly-Clark Co., Neenah, Wis., has been appointed a member of the TAPPI Appropriations Committee. He will serve with John L. Parsons, Chairman, A. E. Bachmann, H. W. Bialkowsky, J. W. Hemphill, Allen Abrams, A. L. Sherwood, J. D. Malcolmson, W. F. Gillespie, K. P. Geohegan, and G. H. Pringle.

Bibliography of Papermaking, 1946–50

Members of the Association have now received the collective Bibliography of Papermaking, 1946–50. This very useful book represents a tremendous amount of work on the part of Clarence J. West of The Institute of Paper Chemistry and Chairman of the TAPPI Bibliography Committee.

The present volume has certain anniversaries related to it insofar as Dr. West is concerned. This year Dr. West reaches his own 65th birthday. He began the preparation of the Papermaking Bibliographies 30 years ago when he was in the employ of Arthur D. Little, Inc. His bibliographies cover about every article or publication relating to the subject since 1900 or 50 years ago.

This is a remarkable service of one man to the pulp and paper industry. His contributions in this field alone have eased the burden and made possible accomplishments by hundreds of individuals and institutions who have needed to know what has gone before so that they might proceed in making further advances to the art.

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TAPPI Plastics Conference

The Plastics Conference of the Technical Association of the Pulp and Paper Industry will be held in Marshall Hall, College of Forestry, State University of New York, Syracuse, N. Y., on Nov. 8–9, 1951. Edwin C. Jahn of the College of Forestry will be General Chairman.

Program of November 8, 1951

8:30–9:30 a.m. Registration
9:30 a.m. Plastics Coatings and Barriers Session
R. T. Nazzaro, Chairman

1. "Recent Advances in Uses of Resins for Paper Coatings and Laminants," by Herbert Wells, American Resinous Chemicals Corp., Peabody, Mass.
2. "The Properties of Saran-Coated Papers Prepared by a Hot Melt Process," by L. F. Swec, The H. P. Smith Paper Co., Chicago, Ill., and H. Lee Clack, Dow Chemical Co., Midland, Mich.
3. "Barrier Materials and Their Application in Military Packaging," by Walter L. Hardy, Leeds Sales Co., New York, N. Y.
4. "Polyamid Resin for Paper Coating," by H. Wittcoff, F. B. Speyer, and M. M. Renfrew, General Mills, Inc., Minneapolis, Minn.

12:15 p. m. Luncheon at Drumlins Country Club
2:00 p.m. Technical Session (contd.)

1. Film: "Pack It Right," by the U. S. Dept. of Defense.
2. Panel: "Problems in Plastics Coatings and Barriers." Walter L. Hardy, Chairman.

Morning session speakers and members of TAPPI Subcommittee on Plastics in Paper Converting will serve as members of the panel.

Program of November 9, 1951

9:30 a.m. Paper Plastics Structural and Laminated Products Session
C. J. Straka, Chairman

1. "Paper Honeycomb Cores for Structural Sandwich Panels," by Robert J. Seidl, U. S. Forest Products Laboratory, Madison, Wis.
2. "Surface or Laminated Constructions as Rodent Repellents," by C. H. Alexander, B. F. Goodrich Chemical Co., Cleveland, Ohio.
3. "Factors Influencing Overlay Transparency of Paper Laminates," by J. F. Blair and D. G. Patterson, American Cyanamid Co., Stamford, Conn.
4. "Known and Unknown Factors Governing Paper for Plastics," by G. H. Hopkins, Taylor Fibre Co., Betzwood, Pa.
5. "Applications and Properties of Paper Base Laminates," by Norman A. Skow, Synthane Corp., Oaks, Pa.

12:15 p.m. Luncheon at Drumlins Country Club
2:00 p.m. Technical Session (contd.)

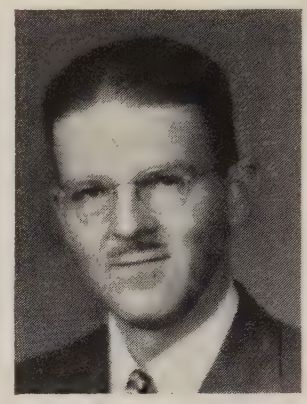
1. Panel: "Problems in Paper Plastics Structural and Laminated Products." Norman A. Skow, Chairman.

Morning session speakers, W. S. Grimes, E. O. Hausmann, and members of the TAPPI Subcommittee on Structural and Fabricated Products will serve as members of the panel.

Hotel room reservations should be made at the Hotel Syracuse or Onondaga Hotel in Syracuse, N. Y. These should be made early. Mention the TAPPI Plastics Conference in making reservations.

Optical Properties Committee

Henry E. Obermanns of the Hammermill Paper Co., Erie, Pa., has succeeded A. H. Croup of the same company as Chairman of the TAPPI Optical Properties Committee in the Testing Division.



Henry E. Obermanns, Chairman, Optical Properties Committee; Hammermill Paper Co., Erie, Pa.

Dr. Obermanns is a 1930 graduate of Yale University in mechanical engineering and received his Ph.D. from The Institute of Paper Chemistry in 1934. He has been employed by the Hammermill Paper Co. since that time except for a leave of absence during World War II. He is an amateur astronomer, and is in charge of all colorimetry, spectrophotometry, photography, and microscopy at Hammermill. Dr. Obermanns will head the delegation of the Technical Association of the Pulp and Paper Industry to the Inter-Society Color Council, of which TAPPI is a member.

Henry Obermanns, Sr., father of Dr. Obermanns, was one of the founders of the Technical Association in 1915.

Coating Conference

The Third Coating Conference of the Technical Association of the Pulp and Paper Industry will be held at the Hotel Sherman, Chicago, Ill., on May 5–6, 1952. (Note change of dates.) The technical program will feature the technology of starch as related to paper coating. Fred E. Culp, Supervisor of Coating Research and Development, Consolidated Water Power & Paper Co., Wisconsin Rapids, Wis., will be the Program Chairman. John H. Heuer of the Great Northern Paper Co., Millinocket, Me., is Chairman of the TAPPI Coating Committee.

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PERSONAL MENTION

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New TAPPI Members

Thomas Aitken, Research Assistant, Abitibi Power & Paper Co. Ltd., Sault Ste. Marie, Ont., Canada, a 1946 graduate of the University of British Columbia.

Glen L. Augspurger, Technical Adviser to Production Manager, Champion Paper & Fibre Co., Hamilton, Ohio, a 1936 graduate of the University of Cincinnati.

Benno J. Bean, Chemical Engineer, National Container Corp. of Wisconsin, Tomahawk, Wis., a 1948 graduate of the University of Wisconsin.

Douglas M. Benoit, Chemist, Fonda Container Co., Inc., St. Albans, Vt., a 1950 graduate of Johns Hopkins University.

Clifton A. Bischoff, Development Engineer, John Waldron Corp., New Brunswick, N. J., a 1942 graduate of Rutgers University.

Claes G. Blom, Exchange Student, Shawano Paper Mills, Shawano, Wis., from The College of Ludvika, Sweden.

William F. Boucher, Supervisor, Lever Brothers Co., Cambridge, Mass., a 1921 graduate of the Massachusetts Institute of Technology.

Stanley J. Boyd, Assistant Superintendent, Sonoco Products Co., Hartsville, S. C., a 1939 graduate of Clemson College.

Oeyvind Bryde, Chief Chemist, Vestfos Cellulosefabrik, Vestfossen, Norway, a graduate of the Technological Institution, Darmstadt, Germany with the Degree of Diplomingenieur.

Ralph W. Buttery, Production Manager and Co-Director, Container Research and Development, Kraft Containers Ltd., Hamilton, Ont., Canada, a 1932 graduate of the University of Toronto.

Donald A. Darby, Draftsman and Instrument Technician, Oregon Pulp & Paper Co., Salem, Ore., a 1943 graduate of Oregon State College.

Frank M. Darrow, Chemical Engineer, Trona, Calif. Attended the University of California.

Alvaro de la Macorra, Student, the University of Maine, Orono, Me., a 1951 graduate of the University of Mexico.

Jacques Duret, Technical Engineer, Societe Centrale des Usines a Papier "Cenpa," Paris, France. Attended the Centrale College of Arts and Manufacture.

Karl Finckh, Co-Proprietor and Managing Director, Reulingen, Wurttemberg, Germany. Attended the Technical College of Stuttgart.

Edward J. Fodden, Project Engineer, The Mead Corp., Chillicothe, Ohio. Attended Pennsylvania State College.

William L. Greenhill, Research Officer, Flax Research Laboratory, Victoria, Australia, a 1927 graduate of the University of Tasmania, with a M.E. degree.

William B. Guerrant, Jr., Plant Manager, Celulosa Nacional, S.A., Tampa, Mexico, a 1945 graduate of the University of North Carolina with a Ph.D. degree.

John L. Hagan, Chief Chemist, Southern Chemical Cotton Co., Chattanooga, Tenn., a 1941 graduate of Georgia School of Technology.

Paul Hilger, Partner and Chief Engineer, Joseck Eck & Sohne, Duesseldorf, Germany. Attended the Technical University, Aachen.

Masao Horio, Professor, Kyoto University, Kyoto, Japan, a 1928 graduate of Kyoto University, with a D. of Tech. degree.

Olin V. Hyde, Student, New York State College of Forestry, Syracuse, N. Y.

Robert S. Ives, Head, Paper and Textile Section, Esselen Research Div., U. S. Testing Co., Boston, Mass., a 1933 graduate of the University of Maine.

Jack E. Jayne, Student, Institute of Paper Chemistry, Appleton, Wis., a 1948 graduate of the University of Wisconsin with an M.S. degree.

Kanichiro Mochizuki, Managing Director, Tokai Pulp Co. Ltd., Shizuoka Prefecture, Japan, a 1914 graduate of Tokyo Technical College.

Martin J. O'Leary, Technologist, National Bureau of Standards, Washington, D. C.

Raymond S. Owen, Management Engineer, Chicago, Ill., a 1920 graduate of the University of Pennsylvania.

Edward W. Petrich, Chemical Engineer, Howard Paper Mills, Inc., Aetna Paper Co., Div., Dayton, Ohio, a 1951 graduate of the University of Cincinnati.

Mark Plunguian, Section Head, Celanese Corp. of America, Summit, N. J., a 1930 graduate of Syracuse University, a 1931 graduate of the University of Idaho, and a 1934 graduate of McGill University.

Richard N. Potter, Chief Chemist, Bird & Son, Inc., Shreveport, La., a 1937 graduate of the University of Illinois.

David D. Reeve, Consulting Engineer, Swanson and Reeve, Vancouver, B. C., Canada, a 1933 graduate of the University of British Columbia.

Alvin T. Sippola, Staff Engineer, Socony-Vacuum Oil Co., Inc., New York, N. Y., a 1931 graduate of the University of Michigan.

Irving Skeist, Technical Director, Newark Paraffin and Parchment Paper Co., Newark, N. J., a 1935 graduate of Worcester Polytechnic Institute, with a Ph.D. degree from the Polytechnic Institute of Brooklyn in 1943.

Edwin Stewart, Production Manager, General Fibre Box Co., Springfield, Mass., a 1927 graduate of Worcester Polytechnic Institute.

Lennart G. Stockman, Chemical Engineer, Cellulosaindustriens Centrallaboratorium, Stockholm, Sweden, a 1944 graduate of the Royal Institute of Technology.

Enrique Suarez S, Chemical Engineer, Fabrica de Papel San Rafael, San Rafael, Estado de Mexico, a 1946 graduate of the University of Mexico.

Seiichi Uchiyama, Factory Manager, Hokuetsu Seishi K.K., Ichikawa-shi, Chiba-ken, Japan, a 1926 graduate of Tohoku Imperial University.

Joseph R. Van Thiel, Instrument Engineer, Combined Locks Paper Co., Combined Locks, Wis., a 1950 graduate of Lawrence College.

Tokiji Watanabe, Director and Chief of Fuji Paper Plant, Kokoku Rayon & Pulp Co. Ltd., Yoshiwara, Shizuoka, Japan, a 1909 graduate of Tokyo Technical College.

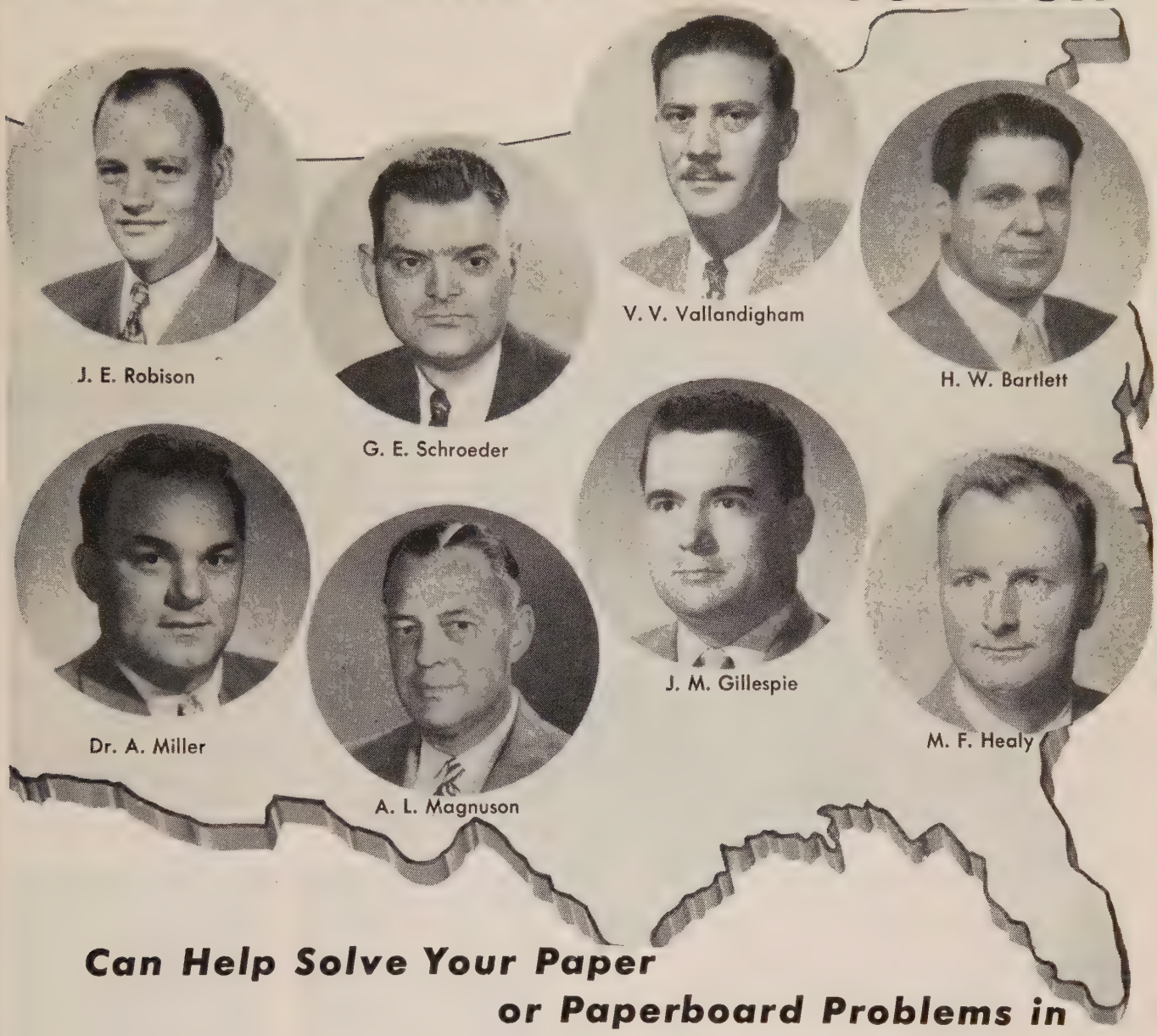
Claude P. Witkowski, Pulp and Paper Mill Director, Regie Industrielle de la Cellulose Coloniale-BP, Abidjan, Ivory Coast, F. W. A.

TAPPI Notes

H. J. Bettner, formerly of the Black-Clawson Co., is now Chief of Inspection, Regional Command, U. S. Government General Services Administration, Washington, D. C.

Frank H. Bopp, formerly Asst. Plant Manager, at Con-

Kelco Technical Service Men



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stantine, Mich., is now in the Purchasing Department, Central Div., American Can Co., Chicago, Ill.

Robyn A. Campbell, formerly Asst. Director of Research, is now Sales Manager, Paper Div., Minnesota & Ontario Paper Co., Minneapolis, Minn.

Charles Carpenter, formerly of the White Star Paper Co., is now Technical Adviser for the New York & Pennsylvania Co., Lock Haven, Pa.

E. A. Charlton is now President of the Central Paper Co., Muskegon, Mich.

Edward T. A. Coughlin, formerly with Chas. T. Main, Inc., is now Chief, Paper and Paper Products Unit, Department of Defense, OQMG, Research & Development, Washington, D. C.

R. C. Crain, formerly of the Nekoosa-Edwards Paper Co., is now General Superintendent, The Columbia River Paper Mills, Vancouver, Wash.

J. Sutton Curtis is now located at the Nash Mills, John Dickinson & Co. Ltd., Hemel, Humpsteat, Herts, England.

Paul E. Daly, formerly of the St. Regis Paper Co., is now Control Technician for the Marathon Corp. of N. Y. Inc., Oswego, N. Y.

Marvin H. Dixon, formerly of the St. Regis Paper Co., is now Power Engineer for the Celotex Corp., Chicago, Ill.

Francis J. Early, formerly of the N. Y. State College of Forestry, is now Chemist for the Ashland Paper Mills, Inc., Ashland, N. H.

W. F. Hathaway is now Superintendent of Paper Making, Kalamazoo Vegetable Parchment Co., Kalamazoo, Mich.

Philip L. Hovey, formerly of the Oxford Miami Paper Co., is now Staff Production Manager for the Oxford Paper Co., New York, N. Y.

Gustaf Jacobsen, formerly of the St. Regis Paper Co., is now Engineer for the Soderhann Machine Mfg. Co., Talladega, Ala.

Victor R. Johnson, formerly Pulp Mill Superintendent of the Central Paper Co., is now Owner of Muskegon Plug Co., Muskegon, Mich.

Harold C. Koch, formerly of the Howard Paper Mills, Inc., is now Technical Director for the Weston Paper & Mfg. Co., St. Mary's, Ohio, and Terre Haute, Ind.

J. M. Krauss has retired as Chief Chemist of the District of Columbia Paper Mills after 31 years of service and is located at 3818 W Street, N. W., Washington, D. C.

C. Roland McCully, formerly of the Weyerhaeuser Timber Co., is now Research Chemist for the Armour Research Foundation, Chicago, Ill.

Sewall J. Moore, formerly of APW Products Co., Inc., is now Chemist in the Paper Chemicals Laboratory of the American Cyanamid Co., Stamford, Conn.

Clyde B. Morgan, formerly of the Eastern Corp., is now President and Director Rayonier, Inc., New York, N. Y.

John G. Morrison, formerly Chemist, is now Assistant to the Mill Manager, Abitibi Power & Paper Co. Ltd., Sault Ste. Marie, Ont., Canada.

Roland A. Packard, formerly of the Lane Paper Machinery Co., is now Chief of the Pulp and Paper Machinery Section, General Industrial Machinery Branch, National Production Authority, Department of Commerce, Washington, D. C.

Robert E. Pflaumer, Vice-President of the American Marietta Co., has removed his offices to 101 E. Ontario Street, Chicago 11, Ill.

John L. Riegel is now Chairman of the Board, Riegel Paper Corp., New York, N. Y.

Walter E. Riley, formerly of the St. John Sulphite Co., is now Pulp and Paper Mill Engineer for Merritt-Chapman & Scott, New York, N. Y.

Richard W. Roberts, formerly student of the Institute of Paper Chemistry, is now Research Chemist for the International Paper Co., Mobile, Ala.

Jorge R. Roldan, Chemist for Cia, Industrial de Atenquique S. A., is now a trainee at the Northern Regional Research Laboratory, Peoria, Ill.

Fred W. Sanders is now Director of Research for the Eastern Corp., South Brewer, Me.

A. J. Saunders, Consulting Engineer, is now located at 1006 Government Street, Victoria, B. C.

Martin M. Scher, formerly of the Ashland Paper Mills, is now Vice-President and General Manager of the Napkin Corp., Saugerties, N. Y.

Maurice G. Scholten, formerly of the APW Products Co., Inc., is now Engineer for the West Virginia Pulp and Paper Co., Mechanicville, N. Y.

Edward W. Schroer, formerly of Carton de Colombia, is now Plant Manager, Container Corp. of America, Cincinnati, Ohio.

David T. Snell, formerly of Robert Gair Co., Inc., Uncasville, Conn. is now Divisions Chemist, Gair Bogota Corp., Bogota, N. J.

William J. Sprau, of the National Gypsum Co., has been transferred from Kalamazoo, Mich., to Buffalo, N. Y., as Production Engineer.

Frederick W Taylor, formerly of the Chain Belt Co., is now with Hewitt-Robins, Inc., Ponte Vedia, Fla.

Raymond H. Taylor, formerly student at the N. Y. State College of Forestry, is now Chemical Engineer for the National Container Corp. of Wisconsin, Tomahawk, Wis.

Frederick B. Wardwell, formerly student at the N. Y. State College of Forestry, is now Research Chemist for the Brown Co., Berlin, N. H.

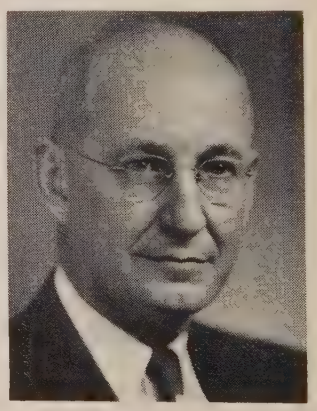
Curt Weill, formerly with Roderich O'Donoghue, is now Designer and Checker in the Industrial Division, Ebasco Services, Inc., New York, N. Y.

Casper (Cap) E. Youngchild, Paper Making Consultant, is now located at 21 Hycrest Court, Appleton, Wis.

W. S. Stuhr, President of the United Board & Carton Corp. Syracuse, N. Y., has succeeded P. M. Loddengaard as the corporate representative of the company in the Technical Association.

Cassius M. Bryan and *F. Nelson Bridgham* have been elected Chairman of the Board and President, respectively, of the Strathmore Paper Co., West Springfield, Mass. They succeed the late George E. Williamson, Past-President of TAPPI, who held both offices. Mr. Bryan joined the Company in 1901 and Mr. Bridgham in 1910.

Cassius M. Bryan



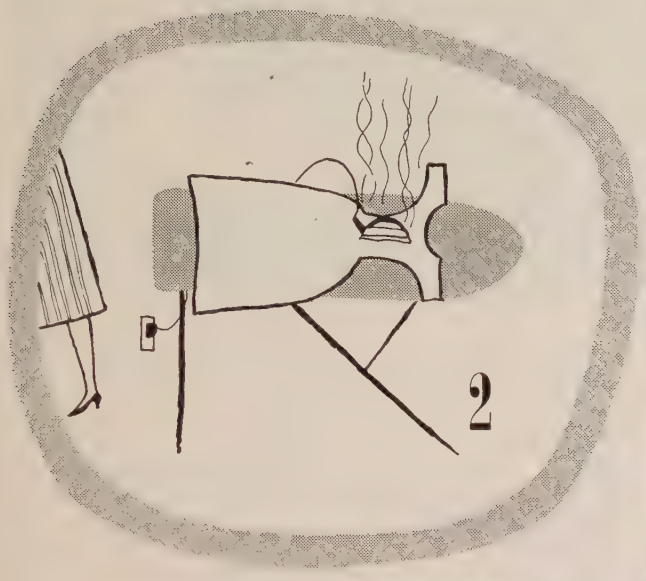
F. Nelson Bridgham

Industry Notes

The National Production Authority, U. S. Department of Commerce, has announced the membership of the Pulp, Paper, and Paperboard Industry Advisory Committee as follows:

M. C. McDonald, President, Chesapeake Corp. of Virginia, West Point, Va.

Purecal irons out coating problems



Is your paper coating as uniform as you'd like? Is it always consistent? Does it allow your equipment to operate at high speeds?

Chances are Purecal* can help. You see, Purecal stabilizes and regulates coating viscosity. If you use other carbonates or clay, even small additions of Purecal will improve your coating. Added to clay alone, it lets you run at higher speeds with less down-time. Added to other calcium carbonates and clay, it irons out the variations they cause. You save money. In addition, you get a coating that's uniform in thickness.

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R. A. McDonald, Exec. Vice-President, Crown Zellerbach Corp., 343 Sansome Street, San Francisco, Cal.
George E. Dyke, President, Robert Gair Co., Inc., 155 E. 44th Street, New York, N. Y.
Hugo Hanson, President, W. C. Hamilton & Sons, Miquon, Pa.
Cola G. Parker, President, Kimberly-Clark Corp., Meenah, Wis.
Leo E. Croy, Exec. Vice-President, Marathon Corp., Rothschild, Wis.
J. D. Zink, Vice-President, Hammermill Paper Co., Erie, Pa.
Sidney Frohman, President, Hinde & Dauch Paper Co., Sandusky, Ohio.
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Stuart Kay, International Paper Co., 220 E. 42nd Street, New York 17, N. Y.
Florence M. Lynch, Vice-President, Pacific Paperboard Co., Longview, Wash.
Amor Hollingsworth, President, Penobscot Chemical & Fiber Co., 213 Congress Street, Boston, Mass.
Sydney Ferguson, Chairman, Mead Corp., Dayton, Ohio.
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Peter S. Paine, President, New York & Pennsylvania Co., Inc., 230 Park Avenue, New York 17, N. Y.
Rex Hovey, Exec. Vice-President, Oxford Paper Co., 230 Park Avenue, New York, N. Y.
John L. Riegel, President, Riegel Paper Corp., 342 Madison Avenue, New York 17, N. Y.
W. J. Dixon, Vice-President, St. Regis Paper Co., 230 Park Avenue, New York, N. Y.
Henry P. Schmidt, President, Schmidt & Ault Paper Co., York, Pa.
R. M. Buckley, Soundview Pulp Co., Everett, Wash.
George Olmstead, Jr., President, S. D. Warren Co., 89 Broad Street, Boston, Mass.

* * *

The following is the organization of the National Production Authority, Pulp, Paper, and Board Division, Department of Commerce, Washington, D. C.

Director—J. W. Maloney
Deputy Director—J. E. Franzen
Consultant—William Chisholm
Administrative Branch—W. L. Neubrick, Chief
Raw Materials—A. W. Howe
Pulpwood—M. H. Collet, F. Heywood,* and J. L. Madden*
Wood Pulp—L. Nicolson, W. Myers, J. L. Ritchie,* and R. H. Evans*
Waste Paper—W. E. Edwards*
Paper Manufacturing—T. H. Mullen, H. E. Whitaker,* H. E. Wright,* and W. T. Jones
Coarse Paper and Products—Daniel F. Smith
Fine and Printing Paper and Products—J. R. Cryan
Waxed and Coated, Special Paper Products—J. V. Melton
Special Food Board—C. H. Morian
Paperboard Manufacturing—J. W. Moore
Container Board—Oswald K. Krogfoss
Boxboard—C. Moyer
Wholesale Paper—T. H. B. Smythe*
Controlled Materials Plan—W. Meaney
Machinery—J. O'Connell
Chemicals and Related Products—H. H. Heller
New Facilities and Equipment—J. Morgan
Certificates of Necessity—L. Nicolson
Conservation—L. V. Hicks
Labor—M. Burns
Foreign—Paul S. Fiske
Industry Advisory Committee—L. V. Hicks
Program and Statistics—Wallace H. Pederson

* Consultants

* * *

The organization of the Pulp, Paper, and Board under the Office of Price Stabilization is as follows:

Forest Products Division—W. J. Damtoft, Acting Director, and Carlton F. Diskin, Counsel
Pulp, Paper, and Board—Rufus I. Worrell, Chief, M. C. Walsh, Asst. Chief, and Quincy Adams, Economist
Pulpwood—C. O. Brown
Market Wood Pulp—Simon Posen
Waste Paper, Rags, and Other Fibers, James T. Flannery and Joseph E. Marcus*
Fine Paper—Charles J. Grant, William G. Luke, Jr.,* and Daniel H. Keck*
Coarse Paper and Products
Wax Paper—Theodore Nealy
Tissue Paper—W. S. Dade
Kraft Paper—John R. Wm. Street*
Wrapping Paper and Bags—Henry S. Daniels*
Shipping Sacks—B. W. Recknagel*
Grocery Bags—Edward F. Melia
Glassine, Greaseproof, and Sulphite Paper—John E. Becker
Paperboard and Paperboard Products—Nicholas M. Brisbois
Containers—N. Chase Flint* and John J. Brossard*
Set-up Boxes, Cans and Tubes, Drums and Pails—Frank J. Canning, W. C. Higgins,* and E. W. Weston
Specialty Board—Charles Wiedman*
Folding Cartons—Robert F. Burroughs*
Food Cartons and Containers—Harry Harvey*

* Consultants

* * *

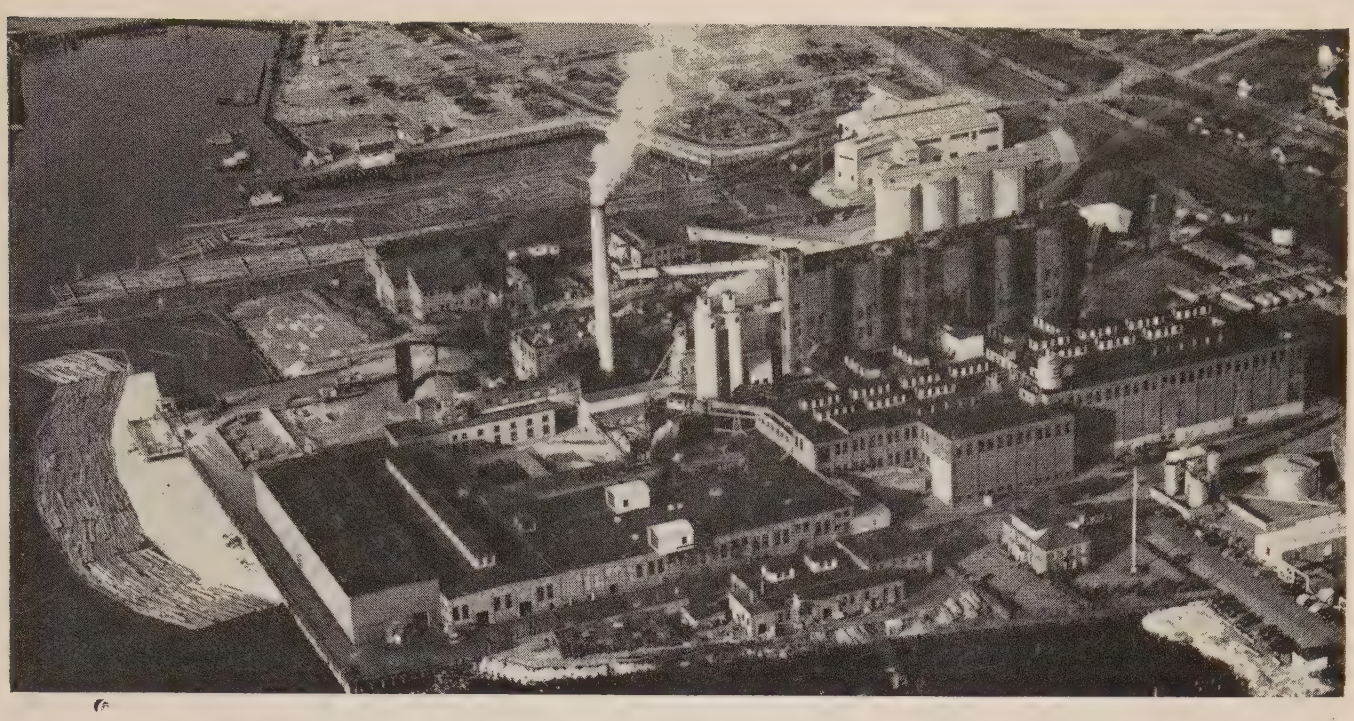
Recent Certificates of Necessity have been issued to the following companies for accelerated tax amortization. (The amount eligible is indicated.)

Brown Co., Berlin, N. H., for sulphur dioxide gas—$548,000
St. Regis Paper Co., Haviland, Me., for kraft pulp—$595,000
Mosinee Paper Mills, Mosinee, Wis., for pulp—$700,000
Fibreboard Products, Inc., Antioch, Calif., for paperboard—$1,439,404.
Ketchikan Pulp & Paper Co., Ketchikan, Alaska, for wood pulp—$36,663,500
Brown Co., Berlin, N. H., for alpha cellulose—$450,000
Champion Paper & Fibre Co., Canton, N. C., for bleached chemical pulp—$1,047,710
Hudson Pulp & Paper Co., Palatka, Fla., for kraft paper—$9,000,000
Brown Paper Mill Co., Inc., West Monroe, La., for kraft paper—$3,160,000
White Star Paper Co., Prescott, Ark., for wood pulp—$15,481,201
Hopper Paper Co., Taylorville, Ill., for fine paper—$1,500,000
St. Regis Paper Co., Pensacola, Fla., for wood pulp—$12,161,000

The program's purpose is to expand private industry's productive capacity quickly to meet mobilization goals. Certificates as an important defense facility permit individuals, companies, or corporations to amortize an authorized amount of a new facility over a five-year period. The accelerated tax write-off program is provided in the Revenue Act of 1950. Prior to the passage of this Act, the period permitted for depreciation of new facilities by the Bureau of Internal Revenue was 20 to 25 years, depending on the normal life usefulness of the facility. The percentage authorized for actual amortization varies according to the type of the facility, the post emergency usefulness of the plant to the owner, and the degree of financial aid deemed necessary to encourage the expansion. The eligible amounts quoted above represent on the average 60% of the amount applied for.

* * *

The N.P.A. has appointed a Water Resources Division with Harvey S. Howe, Director, to avoid the mistakes in World War II, when hundreds of plants were built without full consideration of their water needs. Unnecessary outlay of valuable materials was required to rectify defects in planning. The division will consist of a number of technical men to plan for industrial, public, and domestic water and disposal of waste and sewerage. Planners of plants can check with the Division on the availability and quality of water in areas selected for plant sites. Mr. Howe has pointed out that a poor grade of water may be adequate for use in a cooking system, but water to be used in processing textiles or paper must be of high quality and without traces of iron.



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SULPHITE PULPS

Although wood pulp producers are using less sulphur per ton than they did a year ago, the sulphur shortage remains the pulp industry's principal problem. All domestic consumers of sulphur are restricted by N.P.A. Order M-69 to 100 per cent of their 1950 rate of use. The N.P.A. has warned the pulp producers that further curtailment may become necessary to keep the United States within the quota set by the International Materials Conference. This quota is 3–4 per cent below the 1950 rate of consumption, and is necessary because the world consumption for sulphur is 1,000,000 tons above the annual production rate.

* * *

The following are the sulphur allocations of the International Materials Conference the third quarter of 1951 (in 1000 long tons):

Country	*Allocation*	*Import Quota*	*Export Quota*
Argentina	8.2	...	...
Australia	31.6	21.6	...
Austria	6.5	6.5	...
Belgium and Luxembourg	17.8	17.7	...
Brazil	13.5	13.5	...
Cuba	2.9	2.9	...
Finland	4.5	4.5	...
France	31.2	27.7	...
French North Africa	4.5	4.5	...
Germany	15.1	5.1	...
India	11.4	11.4	...
Israel	1.0	1.0	...
Italy	36.0	...	17.7
Netherlands	0.6	0.5	...
New Zealand	16.6	16.6	...
Norway	6.3	...	18.7
South Africa	16.2	16.2	...
Sweden	15.1	11.6	...
Switzerland	6.8	6.8	...
United Kingdom	106.3	105.0	...
United States and Canada	1050.0	...	250.0
Oil Refineries in Lebanon Trinidad, Iran, Indonesia, etc.	8.5	8.5	...
Other Countries	4.8	4.8	...
Total	1415.4	286.4	286.4

The present plan carries no pricing provisions (tungsten price was fixed at $65) but this will have to be provided for. More I.M.C. allocations are expected. A newsprint order is expected soon.

* * *

The Brown Co., Berlin, N. H., has completed plans for the installation of a Dorrco Fluo Solids System to produce 13% sulphur dioxide gas from pyrrhotite concentrates containing but 35% sulphur. The capacity will be equivalent to 9000 tons of sulphur per year for use in their sulphite acid system. The present plans call for eventually doubling the installation. The installation will be the first in which relatively low sulphur-content pyrrhotite will be successfully roasted without the use of extraneous heat according to the Dorr Co. The cost of the sulphur dioxide is expected to be equivalent to $24 per ton delivered. This is less than the current delivered price of brimstone at the mill.

* * *

The Senate Post Office Committee has approved S 1046 designed to boost mail revenue nearly $30 million yearly. This bill would increase the penny postal card to 2 cents; first-class mail from 3 to 4 cents; the 6-cent air mail rate to 8 cents; second-class mail rates would increase 10 per cent each year for three years, making a total of 30%. Third class mail, after payment of the usual $10 fee, would rise from the present 1-cent rate by $^1/_2$ cent in each of two successive years; special delivery service would be lowered from 23 cents to 20 cents, and no other changes made in special service charges.

The largest sale of National Forest Timber ever made has been completed by the Forest Service, U.S.D.A., with the awarding of a contract for 1,500,000,000 cubic feet of Alaskan pulp timber to the Ketchikan Pulp and Paper Co., Bellingham, Wash. This is sufficient to supply a pulp mill of 500 daily tons capacity for 50 years. The timber is located in the Tongas National Forest in southeast Alaska.

The sale is the result of a 30-year effort by the Forest Service to bring the pulp and paper industry to Alaska. The contract requires the purchaser to build a pulp mill of at least 300 tons daily capacity in Alaska which will employ an estimated 800 persons. A site was acquired for the mill at Ward Cove, near Ketchikan, Alaska.

The Forest Service officials state that additional pulp mills may be constructed in the area, where sufficient timber exists to support 5 or 6 mills of similar size. The pulpwood is to be cut on a sustained yield basis, safeguarding of salmon spawning streams and preservation of scenic values. The sale was made on the basis of a 50-year cutting contract expiring June 30, 2004. The company has agreed to pay 85 cents per 100 cubic feet for pulp timber up to July 1, 1964.

* * *

One of the largest orders for torula yeast ever booked was received recently by the experimental sulphite liquor treatment plant located at the Rhinelander Paper Co., Rhinelander, Wis. It came from one of America's largest pet food manufacturers. Thus far, marketing the large volume of yeast produced has been the big problem of the Rhinelander plant, which at times has had in its warehouses as much as 1,200,000 pounds, or six months total output. This sale of 250 tons for dog food exhausted the storage supply. The use of torula yeast as a vitamin fortifier in small animal foods was pioneered by an Indiana manufacturer working closely with Dr. T. D. Lucky, nutritionist at Notre Dame University. The yeast is produced at Rhinelander to reduce stream pollution.

* * *

Many wastepaper packers and dealers are seeking government priorities for the purchase of new baling presses in order to replace worn-out bales or to augment their present equipment.

The N.P.A. advises that undue delays in having such applications acted upon will be minimized if the applicant will state fully the following items.

1. Name and address of applicant firm.
2. Name and address of supplier, i.e., the company from which the equipment has been ordered.
3. Copy of the order, showing date of order.
4. Order number of form with order number of supplier.
5. Type of merchandise ordered with accessories.
6. Dollar value, total.
7. Date when delivery must be made.

Along with these data a letter should be attached showing the average weekly tonnage of waste paper delivered to consuming mills, or others, with grades, and names of mills or the consignees. This should be mailed to National Production Authority, Pulp, Paper and Paperboard Division, Attention William Edwards, Consultant, Wastepaper, New G.A.O. Bldg., Second Floor, Section 2 Q 8, Washington 25, D. C.

Telephone calls to Mr. Edwards should be made to Washington, D. C., Sterling 5200, Extension 5119 or 5120.

* * *

Pulpwood production costs in southeast Arkansas have more than tripled in the past ten years according to a report of the Southern Forest Experiment Station, New Orleans, La. In 1940, it cost $3.45 to cut, load, and deliver a cord of wood to the railroad or mill. By 1945 costs had risen to $7.23. In 1950 they were $11.14. The report based on a survey of nine pulpwood cutting operations states that costs of felling and

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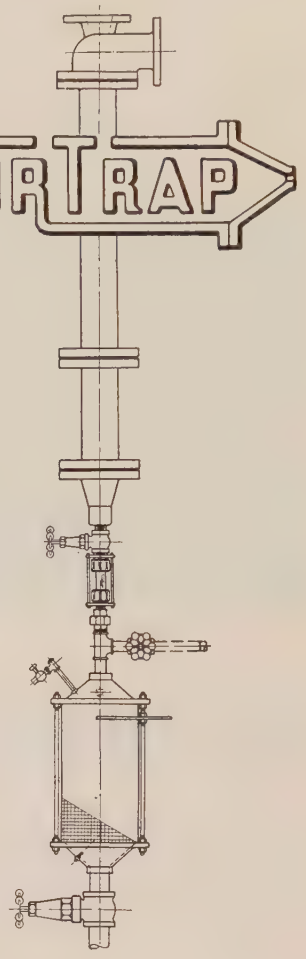

Over 265 Mills in the United States are satisfied users.

72.7 Per Cent of these have REPEATED their Vortrap orders.

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bucking have doubled in the last ten years. The cost of bunching, loading, unloading, and delay has risen 269%, and hauling cost is up 227%. The total average cost of delivering wood today is 223% more than in 1940. Mechanization is more complete and equipment is costlier than ever before. Nearly all contractors use chain saws and supplement them with bow saws. The two-man crosscut saw, in general used to about 1943, has almost disappeared.

There is a trend toward larger and more powerful trucks. Up to 1945 nearly all trucks were $1^1/_2$ tons, but half of those observed in 1950 were two-ton or larger. The average load of wood is 2.5 cords, as contrasted with 2 cords in earlier years. The average one-way haul has increased from 8 miles to about 15. A new expense is the work truck used to haul wood crews to and from the job. Manpower efficiency in 1950 was about the same as in 1940. The tremendous increase in pulpwood production cost over the last ten years can practically all be charged to greatly increased wages and cost of equipment. Only a small percentage can be charged to increased length of haul.

* * *

On Aug. 1 the corporate name of Cornell Wood Products Co. and its Hummel & Downing Division became Cornell Paperboard Products Co. There will be no change in personnel or ownership.

* * *

Leon L. Bertram is now assistant manager of the Virginia Cellulose plant of Hercules Powder Co., Hopewell, Va. He joined the Hopewell plant as a chemist in 1941.

* * *

Brown Co., Berlin, N. H., has issued a 56-page illustrated booklet entitled "Green Harvest." The purpose of the booklet is to make available to Brown Co. pulpwood producers the latest information on forest management and operating practices.

* * *

When powdered coal is burned under modern conditions, the ash is produced in the form of glassy spheres, so finely divided that they fly up and out of the stacks and so are called fly ash. The necessity for large-scale users of powdered coal to prevent their fly ash from settling on neighboring communities has raised bothersome and expensive problems of collecting and disposing of the material. For many years economically feasible uses for fly ash have been sought.

One of the most promising uses is as a partial substitute for cement in concrete. The U. S. Bureau of Reclamation has dramatically emphasized the merits of this application with the announcement that fly ash, bought in Chicago at about one dollar per ton and freighted to Montana at about eleven dollars per ton, has nevertheless saved the government some two million dollars in the construction of Hungry Horse Dam. In addition to the economic advantages, fly ash imparts other desirable properties to concrete, especially improved workability and lower heat of setting, which last is particularly important in massive structures like dams.

Not all fly ashes are identical. Variations arising from different types of coals and combustion equipment require modifications of concrete formulations in order to realize the maximum saving and improvement from using fly ash. The Institute is now engaged in a twofold program for the Alabama Power Company and the Georgia Power Company. It involves (1) determining the properties of their fly ashes and (2) designing optimum formulations for concrete using these fly ashes.

It has already been demonstrated that, although the fly ashes of these Southern power companies are quite different from those used by the Bureau of Reclamation, concrete of highly desirable properties can be made with them.

In order to help stimulate interest in the practical utilization of fly ash, the Nashville Coal Company sponsored in 1949 an extensive survey of the literature on utilization. Two hundred copies of a report on the survey were requested and distributed.

* * *

The fatty acids from nine Finnish tall oils were analyzed both by spectrophotometric and chemical methods which were partially in satisfactory agreement, but in three cases considerable deviations were observed. According to the spectrophotometric method the isolated fatty acids showed a 0.6–2.0% total linoleic acid content (0.37–0.88% normal linoleic acid) and a 37–64% total linoleic acid content (8–25% conjugated and 27–47% normal linoleic acid). Furthermore, they contained 28–51% oleic acid, possibly small amounts of tetraene acids and 6.3–18.3% saturated acids. The highest linoleic acid and lowest saturated acid contents were found for Northern Finland tall oils. The differences in fatty acid composition of the various samples are strong enough to be taken into account when the tall oils are applied to varied technical uses.

* * *

Equipment is now being installed at the Package Development Laboratory Div. of the Engineers Research and De-

New incline impact testing device just completed at Package Research Laboratory

velopment Laboratories, Fort Belvoir, Va. The Laboratory will have the most modern equipment in the Country.

* * *

John H. Truesdale has been appointed Technical Service Manager for Olin Products Co., Inc., 655 Madison Avenue, New York, N. Y. This company will distribute Olin cellophane when production begins at Pisgah Forest in the fall. Mr. Truesdale was formerly Superintendent of the film department of E. I. du Pont de Nemours & Co., Inc., at Old Hickory, Tenn.

* * *

Forest fire losses in the United States during 1950 were the second lowest in history. The Forest Service Report shows that 208,402 fires burned 15,518,540 acres of forest land. This is an increase in acreage and number of fires over the all time record low established in 1949 when 193,774 fires burned 15,397,419 acres. Only $^2/_3$ of 1% of the nation's forest area under organized protection were burned in 1950. About 17.7% of unprotected forest land was swept by fire. Three quarters of all the woodland burned last year was without organized protection. The eleven Southern states lying

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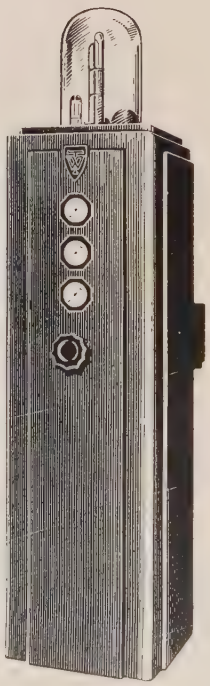
Your nearest W&T Representative—one of a nationwide W&T Service Organization—will be glad to give you details on Break-Point Chlorination for your fresh water supply and chloramine or chemical treatment for stock and white water system. Take the first step toward a slime-free mill. Call him today.



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south of Virginia again showed the largest acreage loss with 13,674,677 acres burned, an increase of 197,794 acres over 1949. Nearly 11 million of these acres lost in the South had no organized protection.

* * *

Seven weavers of fiber fabric who make about 80% of the annual 18 million yard output have formed the Fibre Fabric group of the Tissue Association. Included in the group are Marlan Corp., New York, N. Y.; Patchogue-Plymouth Mills Corp., Lawrence, Mass.; Southern Mills, Inc., Senoia, Ga.; Swift Mfg. Co., Columbus, Ga.; and E. W. Twitchell Co. Inc., Philadelphia, Pa. The group intends to initiate a program of product research aimed at further development of a number of the more than 100 uses for fiber fabric already known. The Tissue Association is located at 122 E. 42nd Street, New York 17, N. Y.

* * *

Merritt W. McGahan has been appointed research assistant to E. C. Jahn of the Research Foundation of the State University of New York to work on chemical debarking at Syracuse. Development of simple and controllable techniques for loosening bark of living trees is the aim of the project which is being jointly sponsored by nine pulp and paper companies and one chemical company.

* * *

A 3800 acre experimental forest, established last year by nine New England pulp and paper companies was officially dedicated at the University of Maine in June. The Penobscot Experimental Forest has been turned over to the U. S. Forest Service under a long-term lease agreement. The land will be used primarily for experiments in management of spruce-fir forest lands. The tract is located eight miles from Bangor.

* * *

The American Forest Products Industries, Inc., 1319 Eighteenth Street, N.W., Washington 6, D. C., has issued a 16-page School Bibliography "American Forests and Their Conservation." This lists booklets, maps, and posters available for schoolroom use.

* * *

A new paper machine is being built by the Pusey & Jones Corp., Wilmington, Del., for the Nekoosa-Edwards Paper Co., Port Edwards, Wis. The machine is scheduled to go into operation in August 1952. The capacity will range from 75 to 150 tons daily, depending on the grade of paper being made. This is about $2^1/_2$ times greater than the capacity of any of the present Nekoosa-Edwards machines. Among the grades to be run are Army wet-strength map bond, writing papers, and base stock for treated food protective papers. Power for the new machine will be supplied by a new boiler with a capacity of 110,000 pounds of steam per hour. Additional electric power required will be supplied by a 6000-kw. turbogenerator that will use the high pressure steam generated by the new boiler facilities.

* * *

The outlook for the 1951–52 seasons rosin supply should be about 2.9 million drums or about 15% less than in 1950–51. The output of tall oil is estimated at 2.6 million drums.

* * *

Utility companies along the Eastern seaboard of the United States are being pressed by the government to switch from oil to coal in their production of gas and electricity. Harry C. Birkhead, Vice-President of the Pennsylvania Coal & Coke Corp., has indicated that this switch is being made. It began a few months ago when oil prices were lifted 30 cents a barrel. Thirty cents per barrel is equivalent to about $1.30 per ton of coal.

* * *

The American Society for Testing Materials will celebrate its 50th anniversary during the week of June 23, 1952, at the Statler Hotel in New York City. The American Chemical Society is celebrating its Diamond Jubilee in New York this September.

* * *

The Plant Maintenance Show and Conference will be held at the Convention Hall in Philadelphia on Jan. 14–17, 1952.

* * *

The General Electric Co., Schenectady 5, N. Y., has issued a 24-page booklet entitled "Electric Power for Industry's Third and Biggest Expansion" (GEA-5600). The publication outlines methods of obtaining electric power equipment for quick expansion with a minimum of critical materials.

A new motor-generator type battery charger, designed to permit mounting on balconies or shelves has been announced by the General Electrics Small and Medium Motors Divisions. This unit is used for charging batteries of lift trucks.

A new productive maintenance service has been announced by G. E. Details may be obtained from H. D. Beale, Manager of the Company's Service Shop Division at Schenectady.

* * *

The American Cyanamid Co., which is now the nation's fourth largest producer of chemicals, has announced the assignment of three of its executives to the Arizona Chemical Co. These are R. C. Swain, Vice-President, who will supervise research and process development; E. D. Powers, Vice-President, who will supervise manufacturing activities; and D. H. W. Felch, Chief Engineer, who will direct engineering activities. They will retain their Cyanamid posts. The Arizona Chemical Co. is owned jointly by Cyanamid and the International Paper Co. and converts kraft with by-products to tall oil, alpha pinene, and beta pinene.

Sheldon T. Dahl has been named West Coast Manager of Cyanamid's Industrial Chemicals Division and Plastics and Resins Division. He will direct sales and production activities. Herbert G. Pratt will become Manager of the San Francisco office of the Division. Both men were with the S. T. Dahl Co. which was acquired by Cyanamid in 1948.

* * *

A. K. Highbee has been appointed Production Manager of the Johns-Manville Building Products Division. He will supervise production of building products at Manville, N. J., Jarrett, Va., Natchez, Miss., Marrero, La., Alexandria, Ind., Waukegan, Ill., and Los Angeles, Watson, and Pittsburg, Calif.

* * *

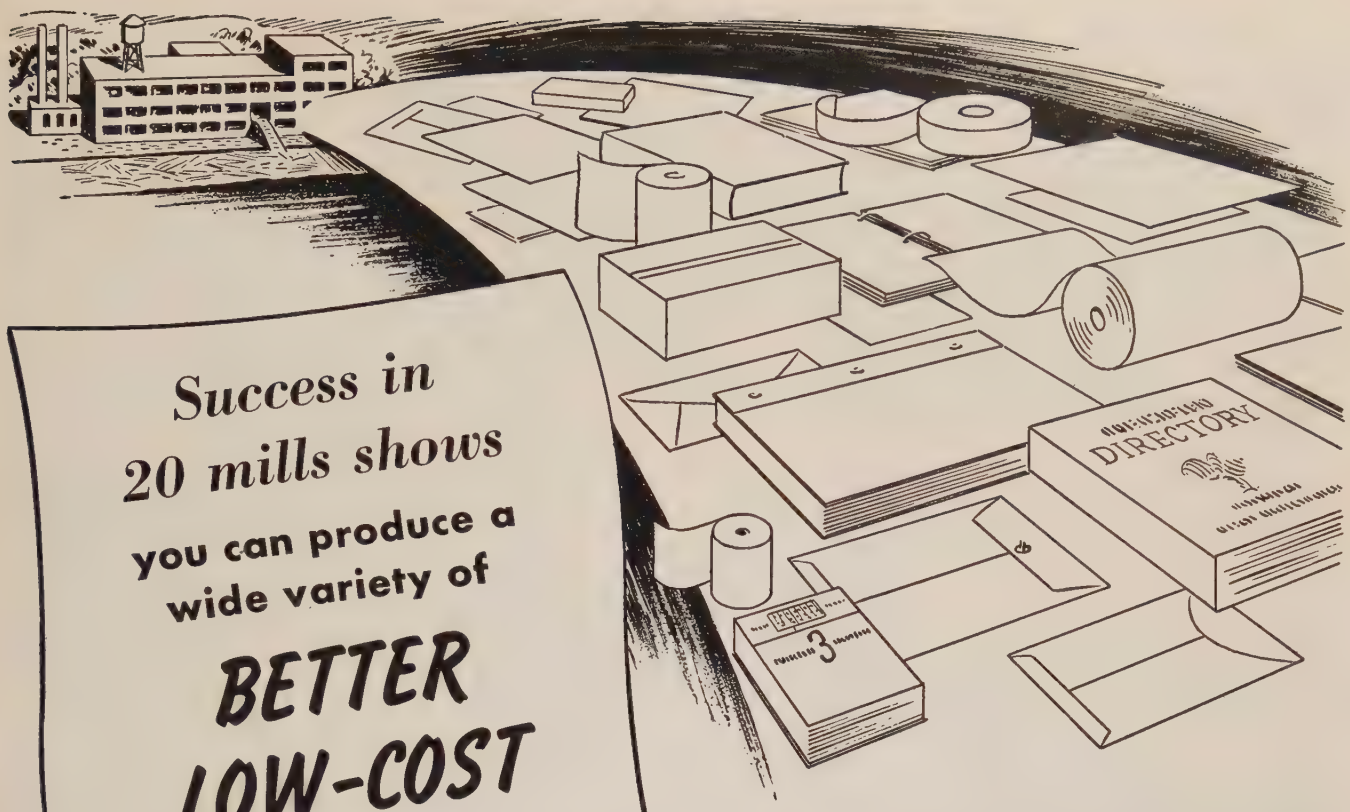
The Philadelphia Electric Co. has placed an order with the Westinghouse Electric Corp. for a 200,000-kw. turbine generator, the largest single-shaft unit ever to be built. It will be installed at Phoenixville, Pa. The turbine will be designed for steam at an initial pressure of 1800 p.s.i. and a temperature of 1000°F., with reheat to 1000°F., and will be a triple exhaust unit. The turbine will be built at South Philadelphia and the generator at East Pittsburgh.

* * *

Goebel A/G at Darmstadt, Germany, will celebrate its 100th anniversary in September 1951.

* * *

The Ingersoll-Rand Co., 11 Broadway, New York 4, N. Y., has issued an 8-page bulletin (7228) on its vertical turbine-type pumps.



Success in 20 mills shows you can produce a wide variety of BETTER LOW-COST PAPERS

Plan now for future production with the DU PONT PEROXIDE PULP BLEACHING PROCESSES

Experience in 20 important U. S. and Canadian mills has shown that Du Pont Peroxide Bleaching can enable you to meet the increasing demand for more and better low-cost papers.

And in mill after mill, the advantages of peroxide bleached groundwood have been apparent . . . savings up to 30% in fiber costs . . . improved brightness permitting the use of more bleached groundwood in the furnish . . . both sulfite and groundwood pulps upgraded!

Adaptable for use in bleaching groundwood, sulfite, soda, kraft and semi-chemical pulps, the Du Pont Pulp Bleaching Processes also provide a means of producing higher quality papers from your recovered paper stocks.

GET THE FACTS FROM DU PONT *today!*

The men who pioneered this modern method of pulp bleaching will be glad to work with you in planning an installation to meet your specific needs. For more information, just clip and mail the coupon below.

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Electrochemicals Dept., Wilmington 98, Delaware

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____Groundwood ____Sulfite ____Soda Pulp ____Kraft

____Semi-chemical pulps ____Waste-paper recovery

*Name*_____

*Position*_____

*Firm*_____

*Address*_____

C. L. Koerner of Portland, Ore., has been appointed representative in Washington, Oregon, and Idaho for J. E. Rhoads & Son of Philadelphia, makers of leather belting and packings.

* * *

Two new names have been adopted for two established products of Hercules Powder Co.'s Paper Makers Chemical Department. A fortified rosin size, formerly known as Dresinate 209, is now identified as Pexol. A companion product, a size additive in dry form, has had its name changed from Dresinate 211 to Size-Aid.

* * *

Diamond Alkali Co. has announced plans for an expansion project at its silicate of soda plant at Dallas, Tex. The Dallas plant is one of six silicate plants Diamond operates throughout the country.

* * *

Traveling well over 30,000 miles during his recent trip to Australia, Tasmania, and New Zealand, Black-Clawson Vice-President, J. D. Haskell, has returned to his home in Fulton, N. Y. Mr. Haskell, also General Manager of the Dilts Machine Works Division, and Managing Director of B-C International Ltd., London subsidiary of The Black-Clawson Co., made the trip as an integral part of an extensive liaison program being carried on by the Black-Clawson world-wide organization.

J. D. Haskell

Tany Agronin

Mr. Haskell was highly impressed with the progressive growth of the Australian paper industry, particularly evidenced by the modernization program being undertaken by Australian Paper Mfgrs., Ltd., at its Petrie, Botany, Maryvale, Broadford, and Fairfield mills. This program includes many items of Shartle stock preparatory equipment now being manufactured in Great Britain.

Also visiting mills in Tasmania and New Zealand which were equally impressive, Mr. Haskell, accompanied by Mrs. Haskell, had a scheduled meeting in New Zealand with R. T. Petrie, Black-Clawson's West Coast Sales Manager, and returned to the States by way of the Pacific.

The Black-Clawson monthly publication, *The Messenger*, Issue No. 286 for July 1951, highlights a recent flying trip to South America by Black-Clawson Vice-President, J. D. Haskell and his wife. Mr. Haskell's comments on the South American tour are both interesting and picturesque. Copies of the reports on mill visits and installations are available from Shartle Bros. Machine Co., Middletown, Ohio.

Tany Agronin, Chief Engineer of Black-Clawson's Shartle Brothers Division, left New York on Aug. 10, for an extended visit to South American paper mills. In South America, Mr. Agronin will consult with paper mill engineers on papermaking problems and will observe operation of BCSD equipment installed in many of South America's paper mills. K. E. Sundqvist, president of Industria Inc., South American representatives of Black-Clawson, will travel to South America with Mr. Agronin.

Mr. Agronin expects to return to Middletown on or around the first of September.

* * *

The design and construction to increase the capacity of Bird & Sons, Shreveport, La., felt mill from 60 to 120 tons per day will be handled by the Rust Engineering Co. of Pittsburgh. The mill was completed by Rust early last year. The project involves the addition of paper-pulping and wood-pulping equipment, twelve new driers in addition to the 27 now in use, and an installation of a new 30,000 hp. boiler. Some press-section changes will be made on the felt machine.

* * *

With the removal of a general overriding Regulation 13 the West Virginia Pulp and Paper Co. has advised its customers of a general adjustment of prices, complying with ceiling price Regulation 22. The adjusted prices, which generally raise the company's rates to those of competitors, mean increases of $5 per ton for liner board; from $5 to $10 per ton for kraft paper grades; and an average of about $7 per ton for white paper grades. In complying with the ceiling price regulation, the paper company's adjusted price schedule includes some rollbacks in specialty pulp products.

* * *

Oil for paints, varnishes, linoleum, and soaps will be a by-product produced by the Crossett Paper Mills, Crossett, Ark. The oil will be the result of acidulation from whole tall oil in a new plant now being constructed.

* * *

Samuel M. Langston Co., Camden, N. J., has isused an exceptionally fine 94-page bound volume entitled "Leadership by Design." This book, written by Robert W. D'Ambry, is the story of the growth of the container industry and how the Samuel M. Langston Co. has contributed toward its advancement in the fifty years of its existence. It is a book that should be in the library of every company engaged in converting paperboard.

* * *

John J. Healy, Jr., has been appointed assistant to Dr. Carroll A. Hochwalt, Vice-President in charge of research and patent activities of the Monsanto Chemical Co. Mr. Healy has been Asst. General Manager of the Merrimac Division of Monsanto at Everett, Mass.

The Merrimac Division has issued a bulletin on Syton C-30, a colloidal solution of hydrated silica in water. It is used in the paper industry for the modification of paper to improve wettability, absorption, and other surface characteristics.

* * *

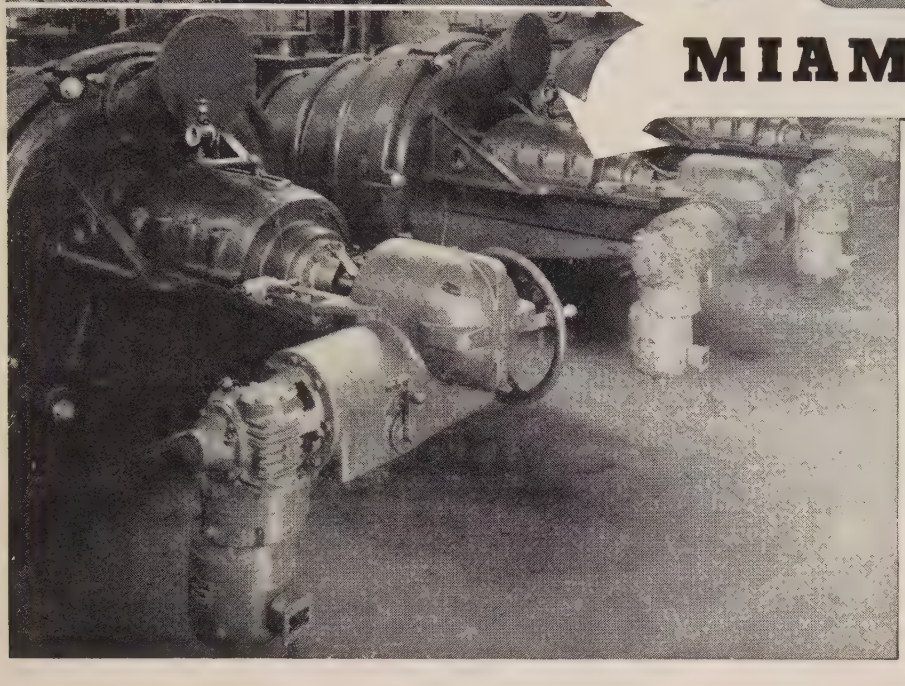
The Chaplin Corp., P. O. Box 1474, Portland, Me., has established a subsidiary—the Chaplin Sales Corp.—to distribute and service the developments of the Chaplin Corp. This company has been associated with the molded pulp industry almost from the first commercially successful production of pie plates and similar articles. More than half of the molded pulp products manufactured in 1950 were produced under one or more Chaplin patents, inventions, or developments.

* * *

At its 103rd commencement, Geneva College awarded the honorary LL.D. degree to Luke E. Sawyer, President of the Babcock & Wilcox Tube Co. of Beaver Falls, Pa.

Babcock & Wilcox has issued a Bulletin T D C 141 giving data on full hardening alloy steel tubing.

MIAMI JORDANS



For sheer ability to stand up and take it, there is no jordan to match a Miami jordan. And that's why so many are sold, both here and abroad.

Another good point in favor of the Miami is the length of the line—10 separate and distinct types and capacities—enabling a buyer to select, not close to what he needs but, exactly what he needs.

With the Duotrol attachment to provide highly sensitive remote plug control, the buyer, in all truth, gets something quite exceptional when he makes it a Miami.

Duotrol on a Miami means, not only sensitive remote plug control but, automatic back-off of the plug in case of stock failure. And that means protection of both plug and shell bars.

Duotrol also available for jordans of other makes already in service. Write.

Get detailed specifications and you'll see why the Miami is that better jordan.

SHARTLE BROTHERS MACHINE CO.

MIDDLETOWN, OHIO

DILTS MACHINE WORKS, Fulton, New York • *Divisions of* THE BLACK-CLAWSON CO., Hamilton, Ohio
Western Sales Office: Mayer Bldg., Portland, Oregon • *Southern Sales Office:* 937 Coventry Road, Decatur, Georgia
Associate: THE ALEXANDER FLECK LTD., Ottawa, Ont. • *Subsidiary:* B-C INTERNATIONAL LTD., Greener House, Haymarket, London, S. W. 1, Eng.

William W. Campbell, Jr., has been named Assistant Sales Manager of the Lockport Felt Co., Newfane, N. Y., to work

William F. Campbell, Jr.

with B. A. Audley, Vice-President in charge of sales. Mr. Campbell has been with Lockport for 17 years and has been a Director of the company since 1938.

* * *

The Glidden Co. will spend $700,000 immediately to expand its production of alpha protein, which is used as an adhesive for making fiber boxes waterproof, 40%. It is used also in wallpaper coatings, insulating board, felt base floor coverings, paper coatings, and paper sizing for writing paper and food wraps. In V-box making, using alpha protein as an adhesive "dry board" bonding has been produced with a minimum amount of adhesive. It dries in 24 hours and matures after application. A strong bond is maintained even after the board is subjected to boiling water.

* * *

The Foxboro Co., Foxboro, Mass., has issued Bulletin 446 on the "Stabiloid Air Cylinder for Pneumatic Roll Loading."

* * *

The G. A. Serlachius Oy., Mantta, Finland, sulphite pulp mill has ordered a new 235 cubic meter sulphite pulp digester made of stainless clad steel. This digester is the first of its kind to be installed in Nordic countries. The clad steel is produced according to the Thyssen process, i.e., a carbon steel plate and stainless steel Remanit 1880-SS are rolled under heat into the wanted thickness and adhere during the process completely together. Surfaces of both materials are before process ground and polished and chemically cleaned before they enter the rolling process and after which they form a consistent material. Both materials are then rolled to the wanted thickness, in this case the stainless steel cladding will have a thickness of 3 mm. The digester plates will be ready cut and prepared for welding at the manufacturers plant and will then be welded together in the digester room. Welding seams are x-rayed.

The new construction has several important advantages not possessed by the acidproof brick lining generally used up to now, i.e., the profitable capacity of the digester is considerably greater, the temperature variations caused when emptying the digester are less injurious and the expensive renewals of the lining with their waste of time are avoided.

Oy Exim AB have arranged the deal and the digester is being produced by the firm Carl Canzler of Duren, Germany.

* * *

After spending three years and almost a million dollars on research, the du Pont Co. has developed a new and economical way to add its synthetic rubber, neoprene, to paper. Instead of coating or saturating the paper, the neoprene is added in latex form to the pulp. The result is a new family of low-cost specialty papers made directly on the paper machine.

Outstanding properties imparted by the neoprene are wet strength, chemical resistance, and all-around improvement in such physical properties as elongation, burst strength, impact strength, scuff resistance, fold endurance, and internal bond strength. These properties have already been utilized in a number of successful applications. Some of them are: linoleum backing, industrial filter paper, imitation leather, gasket paper, multiwall bag paper, and general packaging paper. Du Pont announced that it will not itself manufacture any of these papers but will supply neoprene latex and technical assistance to the paper industry.

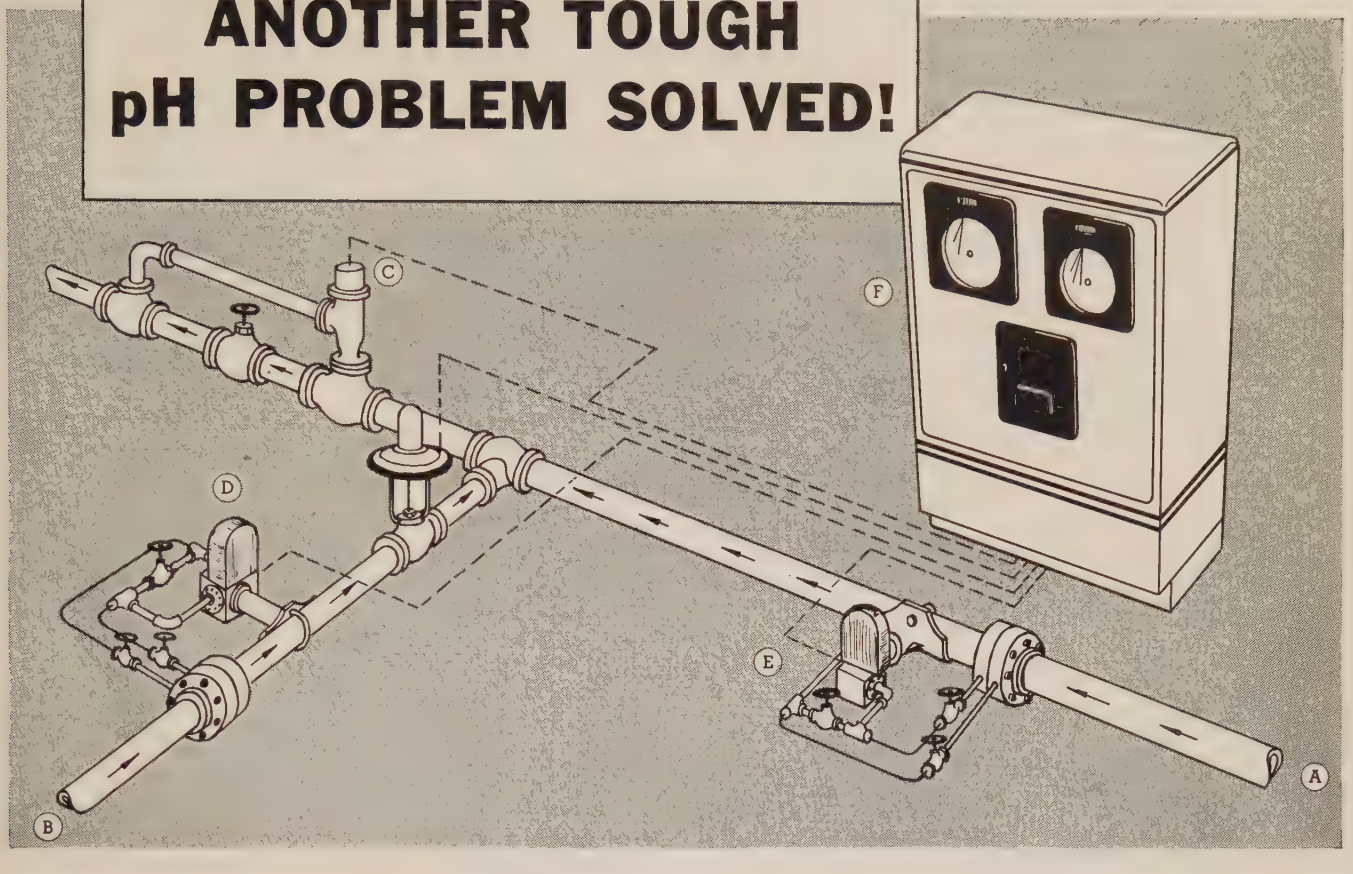
Although the company has been working on the project since 1948, announcement of neoprene-treated paper has been held until research could establish two points—first, that it could be made on standard paper machines and second, that it would have useful advantages over existing specialty and standard papers. Properties of the paper have been evaluated and found commercially promising, the company says, and a new neoprene latex has been developed that can be incorporated in the paper without changing standard mill equipment or practice. The latex is added ahead of the wire, usually at the beater or headbox, and cured in the drier sections to produce good physical properties in the paper as it comes from the machine.

With every indication of the paper's acceptability, both to paper manufacturers and paper users, du Pont has launched a broad program to develop applications. It also has just finished a complete new paper laboratory at Deepwater Point, N. J., for technical service and product development.

"The opening of this new paper laboratory is a milestone in our continuing effort to develop the usefulness of neoprene latex as an additive to paper," says Dr. Samuel Lenher, assistant general manager of du Pont's Organic Chemicals Dept. "Every effort has been made to provide facilities second to none for studying the technical problems of paper making. I am sure that the union here of neoprene and paper will result in a long succession of intriguing new products."

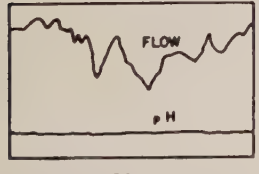
Sheet forming equipment in Du Pont's new paper laboratory

ANOTHER TOUGH pH PROBLEM SOLVED!



. . . by FOXBORO Coordinated Control

THE PROBLEM: To control the pH of fluid (A), a corrosive material varying both in volume and concentration. Flow and unadjusted pH of (A) are shown in curves (left). Since there is no capacity in the system, the high rate of change of flow makes simple pH control inadequate. Adjusting chemical (B) is in a head tank and has constant concentration.



THE SOLUTION: Flow ratio control is employed to maintain the flow of (B) in precise relation to the varying flow of (A). The ratio itself is continuously adjusted by a pH controller. Flow measurements are transmitted to the ratio controller by stainless steel differential pressure cells (D) and (E), while pH is measured at a point (C) where the reaction is complete.

INSTRUMENTATION: *Foxboro d/p Cells* (D) and (E) are mercury-less, highly accurate and corrosion-free. Max. working pressure, 1500 psi. Min. differential range, 0-100".

Flow-Ratio Receiver-Controller, with Pneumaticset — a Model 40 Stabilog*, having proportional and automatic reset control-action.

pH Dynalog* Electronic Controller provides continuous *stepless* balancing. Unmatched sensitivity, response, and accuracy. No slide wires. Range 3-10 pH. Provides Pneumaticset control with proportional reset and derivative (Hyper-Reset) action. pH flowtype electrode assembly for pressures up to 30 psi. Maximum temperature 194°F.

Cabinet (F) is of dustproof construction, rust-proof finish, with removable instrument panel. All instruments completely wired and piped before shipment.

The same facilities and engineering skill that produced the solution above are available to help find the most effective answer to your specific pH control problems. Why not discuss them with your nearby Foxboro engineer? Send for pH Bulletin 430. **The Foxboro Company, 789 Neponset Ave., Foxboro, Mass., U.S.A.**

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FOXBORO REG. U. S. PAT. OFF. **COORDINATED CONTROL**

Properties of Neoprene Treated Paper

Addition of neoprene gives paper a unique combination of properties that is highly desirable in many applications.

Tensile strength: Small amounts of neoprene produce remarkable improvement in wet strength and a little improvement in dry strength. For instance, tests were run on a 60-pound unbleached kraft with these results:

	No neoprene added	*2% neoprene added*
Dry tensile, lb./in. width	50	55
Wet tensile, lb./in. width (immersed 24 hr. in water)	3	19

The 2% neoprene, while it adds only 10% to the dry tensile, adds 530% to the wet tensile.

Elongation: Addition of neoprene substantially increases elongation in both the machine and cross-machine direction. For example, in a 60-pound kraft bag paper, addition of 2.5% neoprene resulted in a 30–33% increase, and 17% neoprene resulted in elongation increases of 165% in the machine direction and 270% in the cross-machine direction.

Bursting strength: Addition of neoprene produces a marked increase in both dry and wet bursting strength. For example, tests run on the same 60-pound kraft used in the tensile tests (above) gave these results:

	No neoprene added	*2% neoprene added*
Dry bursting strength, pts.	59	72
Wet bursting strength, pts. (immersed 24 hr. in water)	6	45

Note that the addition of 2% neoprene improved the dry burst by 22% and the wet burst by 650%.

Impact resistance: Increase in elongation obtained by adding neoprene to paper is more significant than that obtained by varying the pulp or method of processing. Neoprene is elastic, and it imparts a degree of elasticity to paper which cannot be obtained by using special pulp or by using non-elastic additives. Careful stress-strain measurements show that a given stress produces higher strain if the paper contains 2 or 3% neoprene. This means greater energy absorbing capacity which, in bag paper for example, would result in material reduction in drop breakage.

Chemical resistance: Tests have shown that neoprene-treated paper retains its strength to a greater extent than does untreated paper or conventional wet-strength paper. In one test, 2-pound weights were suspended from 1-inch strips of kraft paper and hung so that the weights and part of the test strips were immersed in a test solution. Three kinds of paper were tested—commercial untreated 60-pound kraft, a commercial wet strength kraft containing resin additive, and the same weight kraft containing 3% neoprene. Each paper was tested in three solutions—plain water, 10% hydrochloric acid, and 10% caustic soda. In water: the untreated paper broke as soon as it was immersed; the resin-treated paper broke after 72 hours; the neoprene-treated paper was still holding when the test was discontinued after 86 hours. In 10% hydrochloric acid: the untreated paper broke immediately; the resin-treated paper broke after 6 minutes; the neoprene-treated paper broke after 4 hours. In 10% caustic soda: the untreated paper broke immediately; the resin-treated paper broke after 6 hours; the neoprene-treated paper broke after 72 hours.

New and improved products made from Neoprene-treated paper

Other properties: Folding endurance, internal bond strength, and scuff resistance are all improved markedly by addition of small amounts of neoprene. Smoothness, gloss, and tear resistance of papers containing neoprene are about the same as similar types of regular paper.

Applications for Neoprene-Treated Paper

There are a great many paper products in which the properties imparted by neoprene will be advantageous. Listed below are a few applications that have been tried, along with the particular properties that are useful in each case.

Multiwall bag: A 70/30 mixture of Southern and Swedish kraft containing 5% neoprene has been tested against normal bag paper of the same weight (60-pound). The neoprene-treated paper showed excellent chemical resistance and was found superior also in the following physical properties:

	No neoprene added	*5% neoprene added*
Energy absorption	9.18	12.95
Impact resistance		
Machine direction	8.97	10.33
Cross-machine direction	9.64	17.77
Puncture resistance, point 1	512	733
Scuff	1250	5650
Softness		
Machine direction	143.0	126.0
Cross-machine direction	56.2	50
Drop test	10	30

Experimental shipments have been made in which standard 4-ply multiwall bags were successfully replaced by a 3-ply construction in which this neoprene-treated paper was used as the outside ply.

Printing paper: Bleached-kraft printing papers containing 2 and 5% neoprene have been made experimentally. They have excellent fold resistance, good resilience, and are very strong. Their high wet strength makes them useful for map paper and waterproof labels.

Filter paper: Porous, unbleached 100-pound kraft containing 5% neoprene is being made on a semicommercial scale for use in industrial filter presses as a replacement for canvas filter cloth. Properties important in this use are wet strength and chemical resistance. The paper costs about $^1/_{14}$ as much as the canvas it replaces.

Tray liners: Unbleached kraft containing 2% neoprene is being used experimentally as a cheap, disposable liner for metal trays used for drying colors and chemicals. The use of such liners keeps sticky materials from adhering to the trays and eliminates cleaning expense. The important properties contributed by neoprene are high internal bond strength, wet strength, and chemical resistance.

Imitation leather: Addition of 25% neoprene to a mixed kraft-rope stock has been found to produce an excellent paper for imitation leather. It has excellent internal bond strength, abrasion resistance, wet strength, and water repellency. Embossability is also very good; impressions are sharp and there

BATHURST POWER & PAPER COMPANY

installs

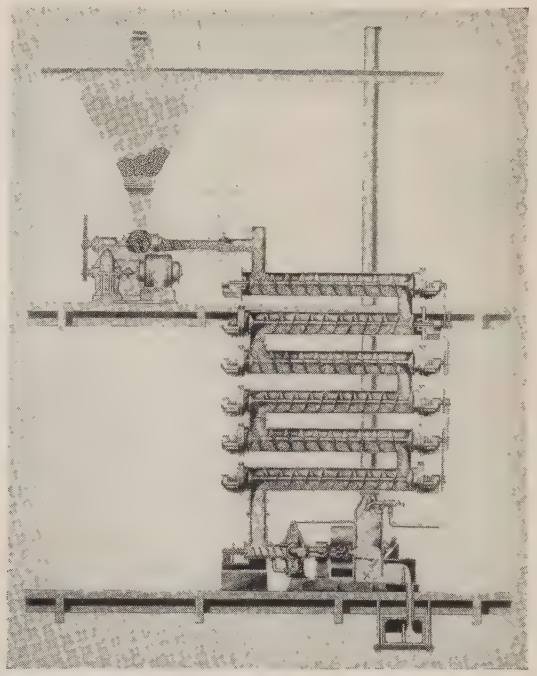
2 CHEMI-PULPERS®

to produce semi-chemical pulp from unbarked, mixed hardwoods for making corrugating board

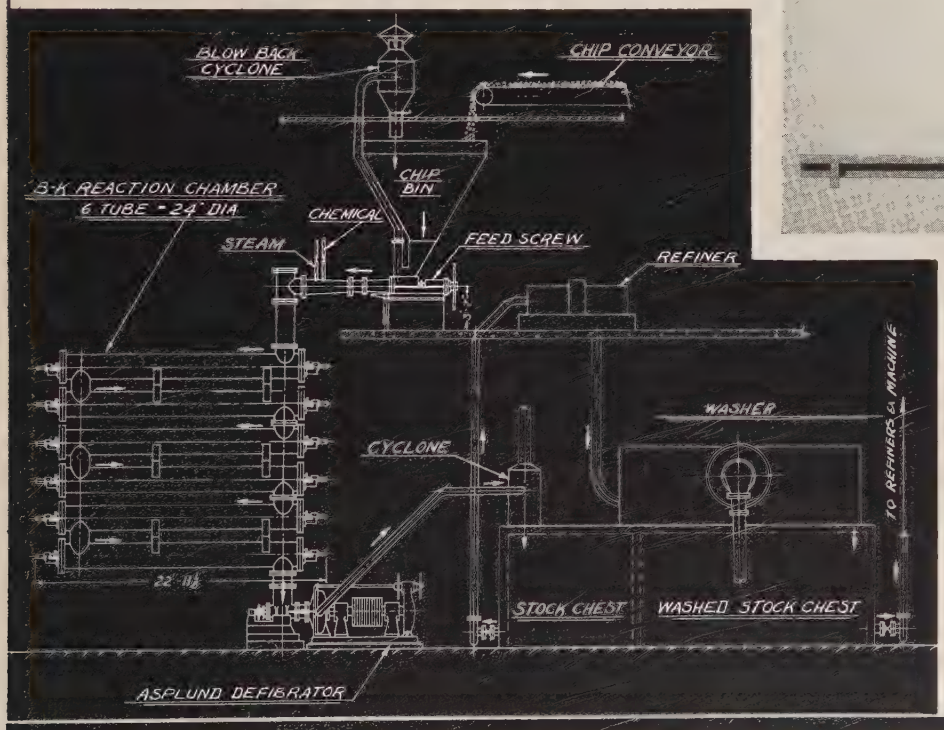
These Chemi-pulper installations comprise two 6-tube units. The operation uses unbarked, mixed hardwoods exclusively together with kraft cooking liquor for producing semi-chemical pulp. Provision was made for two additional pipes in each Chemi-pulper for future requirements.

The Chemi-pulpers operate continuously, producing a uniform pulp for making their high-grade corrugating board.

These Chemi-pulpers will effect substantial savings in steam, power and labor costs. Compact design and construction permitted a saving in building space.



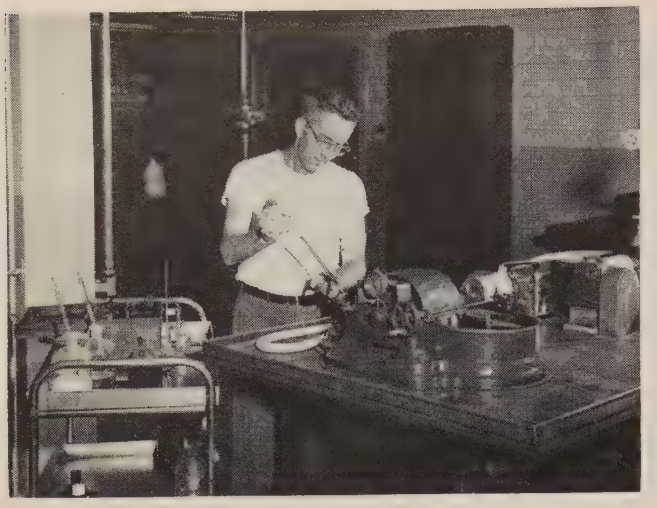
Multiple-unit
B-K REACTION CHAMBER
with Asplund Defibrator



Flow drawing shows operation of one of the two Chemi-pulpers installed in Bathurst Power & Paper Company mill for producing semi-chemical pulp for corrugating board.

PAPER and INDUSTRIAL APPLIANCES, INC.
122 EAST 42nd STREET ● NEW YORK 17, N. Y.

MANUFACTURED AND SOLD IN CANADA BY ALEXANDER FLECK LIMITED, OTTAWA, ONTARIO.



Adding latex stabilizer to pulp in an experimental beater

is no decrease in over-all thickness. This paper would also be suitable for insoling and gasketing.

Masking paper base: Bleached kraft containing 50% neoprene has been used in this application to replace standard saturated sheets containing 100–150% GR-S synthetic rubber. It has high internal bond strength, good pliability and is much lower in cost.

Sandpaper base: Semibleached kraft containing 15% neoprene has been used experimentally to replace 100% rope stock. Neoprene contributes high wet strength and excellent wet or dry abrasion resistance, and its improvement of internal bond strength permits lighter beaten stocks to be used.

Linoleum backing: Standard asphalt-saturated linoleum felt has been replaced by a low-cost paper stock containing 7.5% neoprene. The neoprene-treated backing is pliable and dosen't get stiff when cold, as asphalt-saturated backing does. Linoleum or plastic wall tile on which the new backing is used is consequently much less troublesome to install and less subject to cracking. Neoprene also imparts high tensile strength, wet strength, and internal bond strength. With the neoprene treated backing there is no danger of smudging walls during installation.

Meat labels: Bleached kraft containing 5% neoprene is being used as marking tags by meat packers in place of regular varnish-coated tag stock. Neoprene gives the required blood and grease resistance.

Creped covers: Unbleached creped kraft containing 5% neoprene is being used to make temporary barrel covers. Neoprene imparts water repellency, tear resistance, wet strength, and chemical resistance.

Laminates: Neoprene is being used as a kraft laminating material to produce a paper laminate with high-fold resistance, excellent impact properties, and good wet strength. It is suitable as furniture wrap, tarpaulins, and baling paper.

New Lab Facilities for Neoprene-Treated Paper

Facilities available to the staff of the new paper laboratory enable services of three general types to be offered to the paper industry: pulp testing as related to use of neoprene, preparation of experimental papers, and testing of experimental papers. In any of these three fields, requests for technical assistance are welcomed.

"As a service organization," says R. H. Walsh of the laboratory's technical staff, "our primary job is to undertake experimental work for manufacturers who wish to know how the addition of neoprene will affect the properties of their paper."

As to pulp testing, the laboratory is equipped to perform such tests as determination of fiber areas, electron microscope studies, measurement of ion exchange capacity, and determination of copper and permanganate numbers.

For the preparation of experimental papers, the laboratory is equipped with the following: four beaters of $^3/_4$, $1^1/_2$, $2^1/_2$, and 5-pound capacity, freeness tester, specially designed 36-inch drum drier, 12 by 12-inch sheetforming equipment, 18-inch press section, 8 by 8 inch Noble & Wood sheetforming machine with variable white water return system. Also available are coating machines, calenders, offset and letterpress printing equipment, and a 40-ton platen press for embossing and laminating studies.

For the third type of service, the testing of experimental papers, the staff has at its disposal—in addition to the standard equipment for porosity, smoothness, fold, etc.—the following specialized research tools: Instron and Tinius-Olsen tensile testers for precise measurement of energy absorption and stress-strain relationships; a unique puncture tester; special resilience and internal bond testers; Scott variable temperature wet tensile tester in which the paper specimen is pulled under water; dry tensile testers arranged to hold and pull specimens at temperatures up to 250°F.; cold boxes for testing impact strength and adhesive strength of laminates at temperatures down to minus 90°F. Fadeometers and Weatherometers are available for discoloration tests. An air-conditioned room is available for testing paper under standard conditions.

"An important feature of the laboratory design," Walsh says, "is the provision for flexibility. We've given ourselves elbow room and enough open floor space to set up special projects as they arise. Equipment has been so installed," he said, "as to permit its arrangement in a variety of combinations simulating paper mill and paper converting operations. All in all, we are confident we have the facilities to make neoprene an important new factor in the paper industry."

OBITUARY

Charles Whitney Morden

Charles W. Morden, President of Morden Machines Co., Portland, Ore., died unexpectedly of a heart condition on July 23, 1951, at his home in Portland.

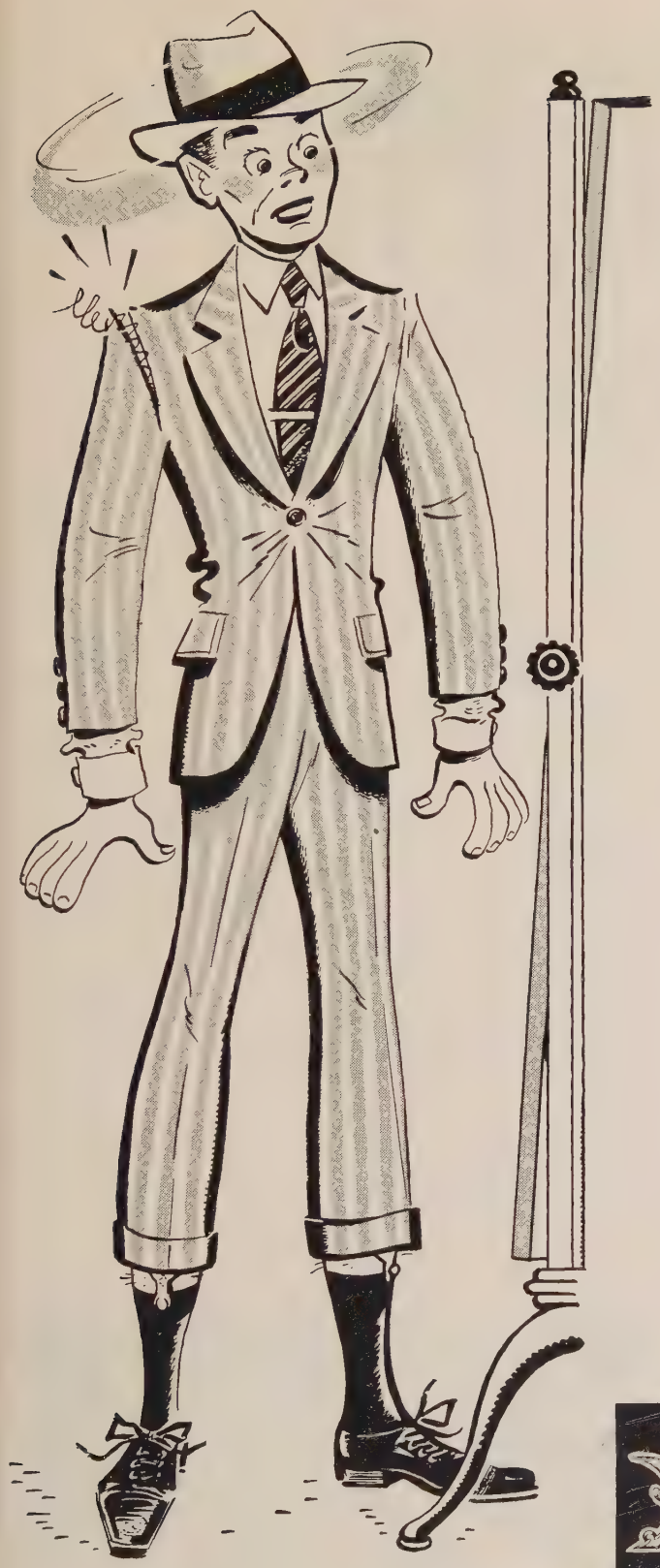
Charles Whitney Morden

Mr. Morden was born in Portland on Jan. 12, 1888, and graduated from the Worcester Polytechnic Institute in 1910. Upon graduation he entered the employ of the Crown Willamette Paper Co. as a draftsman and later as an engineer and resident manager at Portland. He was with the Crown organization for seventeen years.

After leaving Crown in 1927, he began the development of stock preparation equipment for pulp and paper mills. In 1931 he founded the Morden Machines Co. for carrying on the development of the Morden Stock Maker and later the Morden Slush-Maker.

He became a member of the Technical Association of the Pulp and Paper Industry in 1919, a few years after the Association was organized in 1915.

Mr. Morden is survived by his wife, Ada, and his son, R. Burke Morden, who, during recent years, has been associated with him as Vice President of Morden Machines Co.



Not everybody takes a "Regular"

As a matter of fact, some men can't find a really perfect fit unless they have their suits tailor-made.

It's that way with the supplies you buy, too. For instance, we have a complete line of standard starches and other corn products for paper mill use; but we are *also* set up to provide you with any *special* formula or product, *tailor-made* to your specifications.

And . . . standard or special . . . you'll want to buy from a company like Anheuser-Busch, whose reputation for products of highest quality, uniformity and dependability is as dominant in the paper industry as it is with retailers and consumers all over the world.

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TAPPI DIVISIONS AND COMMITTEES

Recent Reports of Activities

Wall Friction Between Pulp and Glazed Tile

During a literature study by the Hydraulics Committee of TAPPI an article entitled, "Pumping of Pulp Mixtures," by K. Klarfelt, was translated from the Norwegian paper journal (*Papir-J.*, nos. 4, 5, and 6, 1942).

The Hydraulics Committee was seeking additional data on pipe friction, but in the course of this article reference was found to a series of tests run during the Spring of 1937 at the pulp mill of Greaker Cellulose Co. on behalf of A. S. Thumes Machine Works to determine power requirements for the circulation of pulp in channel-type bleach chests.

The pertinent data from this series of tests are summarized in Fig. 1 which gives wall friction in pounds per square foot of wall surface plotted against moisture-free consistency.

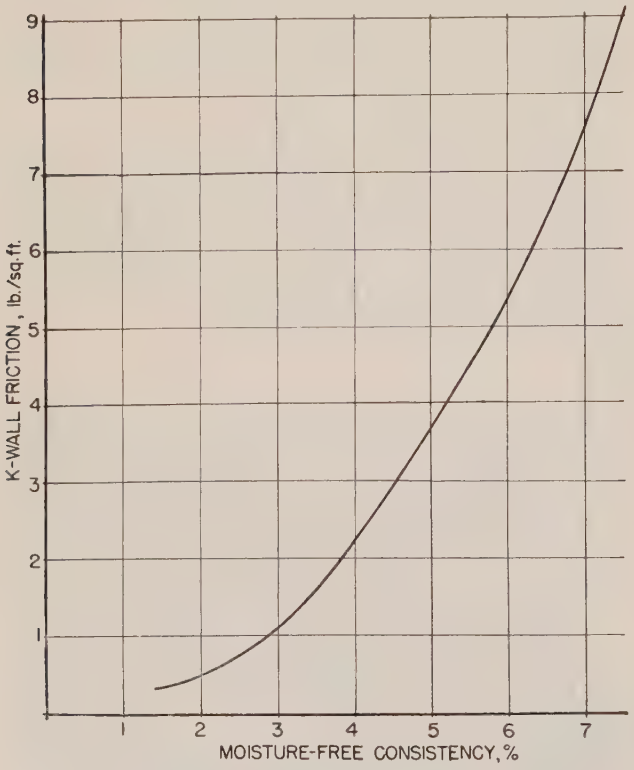

Fig. 1. Wall friction between pulp and glazed tile

Bleached and unbleached sulphite
Freeness—880 to 870 S.R.
Temperature—61 to 97° F.
Velocity—16 to 28 ft./sec.

The bleach chests were of 74,000 gallons capacity, holding 16 to 20 tons of moisture-free pulp and were lined with glazed tile. Resistance increased with the velocity but in the velocity range studied from 0.16 to 0.28 foot per second it could be considered to be constant. Readings were taken all through the bleaching process and the results on bleached and unbleached sulphite were approximately the same.

In calculating the wall area, the author doubled the actual figure for distance around the turn-arounds as an assumed correction for the inner friction between layers.

Electrical Engineering Committee

Electric Cable Subcommittee

The second meeting of the TAPPI Subcommittee on Cable convened in the Conference Room at the St. Regis Bag Plant, Cantonment, Fla., at 10:04 a.m., July 27, 1951, with S. J. Rosch of Anaconda Wire & Cable Co., S. C. Cooke of General Electric Co., R. C. Graham of Rome Cable Corp. E. W. Davis of Simplex Wire & Cable Co., G. W. Zink of Haverstraw Cable & Wire Division, Phelps Dodge Copper Products Corp., E. G. Sturdevant of the United States Rubber Co., Ray W. Foster of Champion Paper & Fibre Co., John Hogan of The Okonite Co., O. A. Smith of Merritt-Chapman & Scott Corp., L. L. Clapp of St. Regis Paper Co., T. J. Manning of The Okonite Co., Douglas Early of the United States Rubber Co., and A. O. Mortenson of the St. Regis Paper Co. present.

Mr. Mortenson: Gentlemen, the hour of convening the second meeting of the Subcommittee on Cable of the Technical Association of the Pulp & Paper Industry has arrived. This, gentlemen, to my mind is a rather splendid turnout to a meeting such as this and I want to let you know that the Association appreciates your help to the fullest. That, perhaps, is just about all I should say in expressing to you a sincere welcome on the part of TAPPI and on the part of St. Regis. I might say too that TAPPI is genuinely appreciative of what the Insulated Power Cable Engineers' Association has done in this instance. We know it will be of immeasurable help to us. We hope, on the other hand, to be of equal help to the Insulated Power Cable Engineers' Association. We think that the service that we can render each other will be equal and mutual.

Without further adieu I think we should come to a very brief résumé of our last meeting. All of you, I believe, received a copy of the minutes of the last meeting, so it is not going to be necessary to read very much of this. (See *Tappi* 34, No. 8: 74A–84A (August, 1951).

Undoubtedly all of you have gone over it. However, I

Group at the Electric Cable Subcommittee meeting held July 27, 1951 at the St. Regis Paper Co., Cantonment, Fla.

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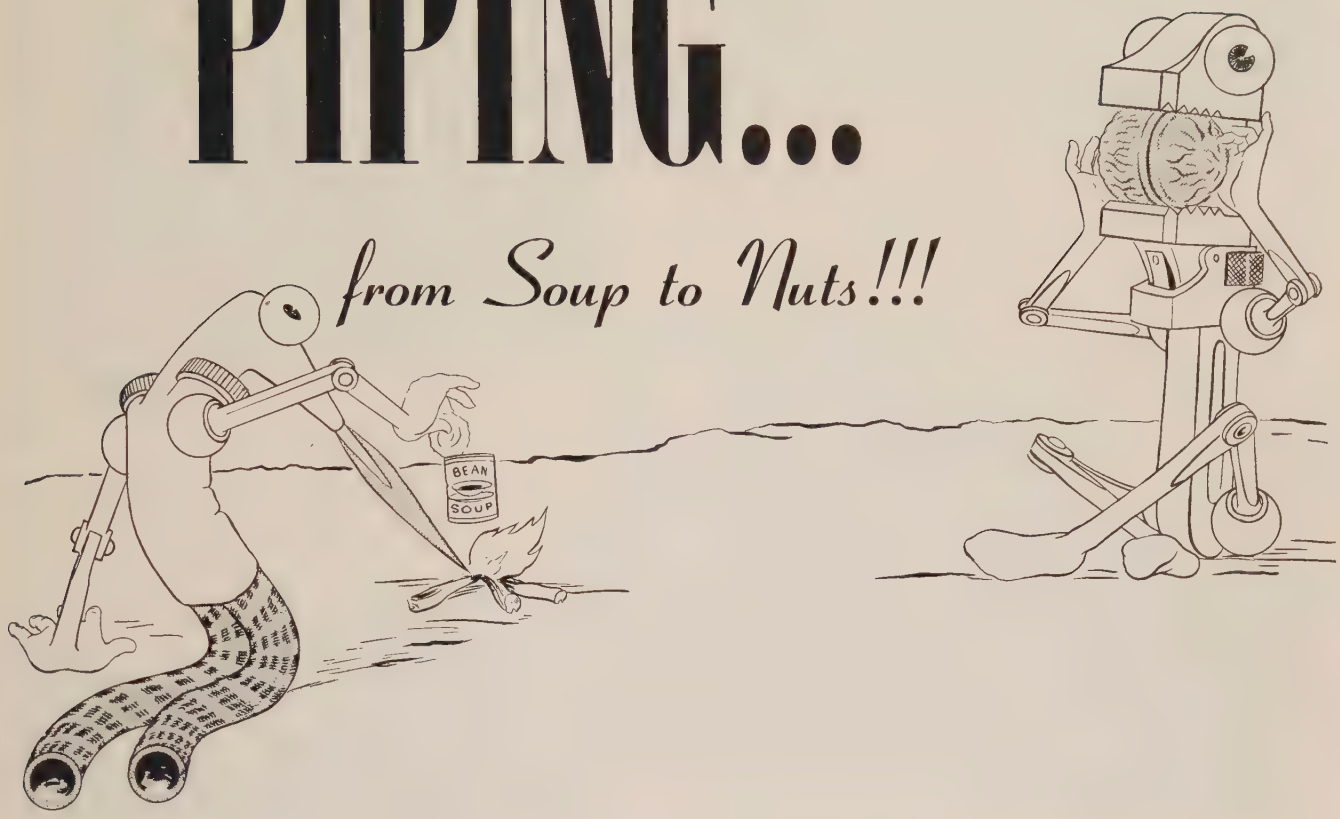

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think that we should restate the purpose of our meeting, both at that time and now. I shall do it by reading a few sentences of my opening welcome May 11.

"We aim to do nothing other than to recommend to our parent organization, TAPPI, specifications from what is in the field today that will serve best in all departments of the industry taking in groundwood, sulphite, sulphate, waste paper, rags, etc. So later when one sets out on a plan of improvement he can use the standards set up by TAPPI with assurance that he is specifying the best that the market affords for every service contemplated.

"I should wind up our résumé of the meeting of May 11 by reading what we told Tom Manning, who came in late that day, about what we had done during the day and that will just about cover everything on the preceding thirteen pages.

(Mr. Mortenson reads pages 13 through 14 of the minutes.)

"Well, so that Tom Manning will know a little bit of what we have done today, he having a casual interest with what we are doing in that he has consented to sit in with us this afternoon as a guest, it is no more than fair to let him know what we have talked about. John Hogan, immediately after we got under way (after the purpose of the meeting had been stated and some of the difficulties encountered in bringing the meeting about had been rehearsed), said that we should look in on what was purchased in the way of power, that was, of course, generated within the industry itself and thought that we would find that the range ran from 480 up to 15 kv. and he suggested rubber-insulated neoprene-sheathed for everything above 4160 (shielded type). Other insulations that we should consider seriously are plastic, varnished cambric, ACV asbestos, felted asbestos, AIA type with asbestos braid for resistors. For any of the applications in the voltage range 440 to 4160 we think interlocked bronze armored cable could be used. After lunch Mr. Clapp raised the question of whether we should use bronze. Certain chemicals encountered in the industry affect bronze detrimentally, he said. That was left as a question to be answered later by Mr. Cooke, I think. In that range 440–4160 standard cable incased in conduit was also strongly suggested. In fact, that's about all that is being used in the industry today. That was, by the way, Mr. Manning, taking into consideration the various departments in sulphate pulp and paper mills south of the Mason and Dixon line. We were prompted by what Larry told us we could expect to subject the cable to in the various departments of a sulphate mill. In the digester room we do the same as in the wood room. In the brown stock washer room we say general plastic, TW type, or RW with neoprene sheath in a room where there is considerable steam, black liquor, etc. Then in the screen room, the alum and size plant we say the same thing as we say for "C." In the jordan room we say the same thing, except that we do say that where we consider aerial cable that we should not consider it too seriously. In the machine room where we encounter 440 to 13,800, rubber insulation neoprene jacket, RH type. In the finishing room and the bag plant and the causticizing and the bleach plant and the evaporator room we duplicate what we said for the wood yard and digester room; except in the bleach plant which is to be investigated by Mr. Cooke and Mr. Hogan because of the chlorine encountered there. In the recovery room, where aside from bad chemical conditions we also have high temperature to contend with, we say the same as the wood yard, except we say the RH type should be used with sufficient additional cross section in the conductor to compensate for the excessive ambient temp. We have found here that certain cables recently installed, rubber-insulated type, had to be removed in a short time due to high temperature which, according to Mr. Hogan, made the insulation brittle and filled it with cracks. We had to pull it out. So to slow up that action we think perhaps that wire or cable of larger cross section should be used. In the machine shop we consider bus duct as the best bet. We have thought about interlocked galvanized armor overhead. In the boiler room we duplicate the recommendation shown for the recovery plant. In the turbine room there it is a toss-up. Voltage from 13,800 down to 2300. For generator leads we considered bus duct. For the auxiliaries we dittoed the RH recommendation found under wood yard and digester. Smith then threw in a suggestion that perhaps AVC should be specified throughout the turbine room. Varnished cambric means lower cost. Then for the lime kiln (feed end and drive) we say the same thing as under the wood yard. Discharge end, where temperature runs higher than in the boiler plants, the suggestion is asbestos or silicon insulation with glass braid. Salt cake storage, most anything will do there. For the service pump house, we say that what will do in the wood yard will do there very nicely. It was suggested that aerial cable had possibilities in getting service to the pump house. The bark burner house came in for the same recommendations as the main power house. On the precipitators we were a bit stumped; 600 to 50,000 volts, with frequencies from 60 cycles to radio. So, for the precipitator equipment itself, where the high voltages and frequencies are employed, our recommendtion is that the manufacturers' recommendations be accepted and that the materials furnished by them be used. For the auxiliary equipment we say rubber-insulated neoprene-jacketed.

"In discussing cable splicing, cable termination, method of making joints, tapping, etc., we concluded that potheads should be used for all outdoor cable terminations. On all big jobs, whether they are just extensive renovation jobs or complete new construction jobs, we think the terminations and joints should be made in accordance with the cable manufacturers' recommendations. We think, too, that the cable manufacturers should supply the materials used in the joints and terminations because no installation is any better than the poorest joint or splice in the system. Of course the big responsibility rests with the overseers of the workman because the best materials are no good if they are not applied right."

Mr. Mortenson: That's it. That was the gist of our last meeting. Are there any errors, omissions, or corrections that should be made?

Mr. Hogan: One thing that came up in my company was that I am quoted as saying that nonshielded cable is used for service up to 3000 volts and shielded for 4000 volts and above. Maybe Miss Miller misunderstood. I think at that time we had quite a discussion. Up to now the nonshielded has been more prominently used for all service up to 5000 volts.

Mr. Mortenson: Can you tell us, John, where that might be in our previous minutes and we will correct it.

Mr. Hogan: Page 3, next to the last paragraph.

Mr. Mortenson: Let me read that quotation as Miss Miller has it and we will let John correct it, and if acceptable we will adopt it.

(Mr. Mortenson quotes Mr. Hogan from minutes May 11.)

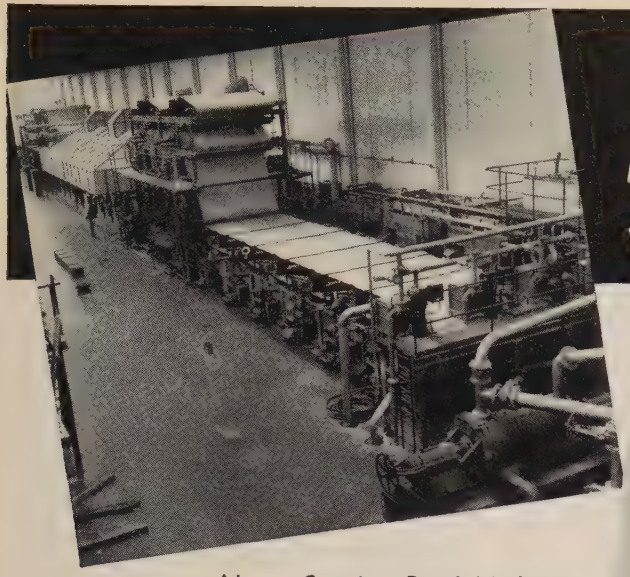
"If you were to manufacture 4160-volt cable, in all probability you would go to a cable with 0.1064-inch rubber insulation. Now right at the minute there is controversy among cable manufacturers with regard to shielded products. Conducting neoprene sheath is quite often used but the results haven't been too good. Nonconducting sheathed type now most generally recommended up to 3000 volts. Shielded cables are generally used for 4000-volt distribution and above."

Mr. Rosch: That should be $^{10}/_{64}$-inch rubber insulation.

Mr. Mortenson: Right. (Correction accepted.) Now John, can you correct the statement as read?

Mr. Hogan: The idea is that outside of varnished cambric lead and braid the most commonly used cable up to 5000 volts has been rubber-insulated cable with neoprene sheath. Whereas the adoption of specifications by IPCEA to require shielding above 3000 volts remains to be seen. If the wire and cable industry generally recommended and brought about the general practic of shielding above 3000 volts the statement made in the previous minutes and attributed to me would be true. Based on the past that has not been the case.

New Sandy Hill Multi-Vat Board Machine with many unusual features



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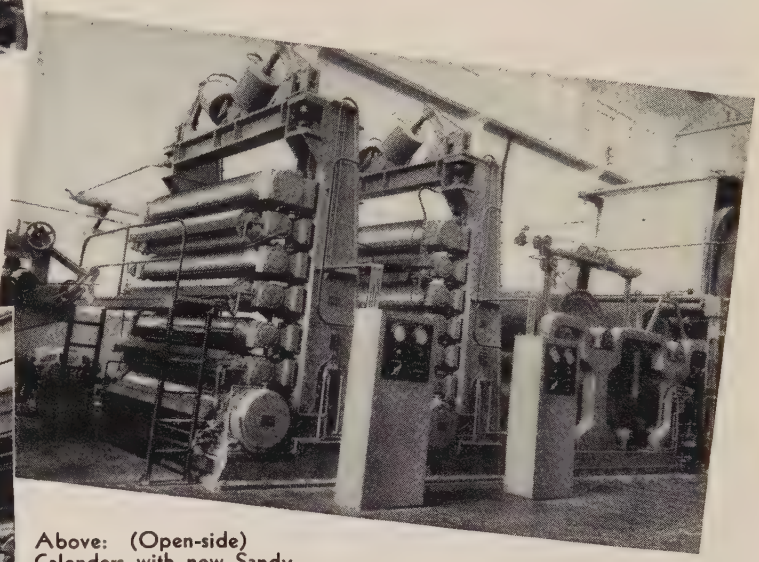
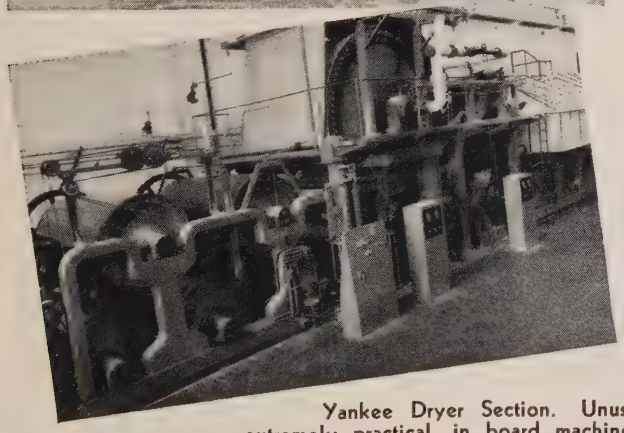
Above: Complete Board Machine. Available overhead room in this plant made possible the special arrangement for cleaning of the top wet felt and the second press felt.

Below: Dryer section showing the sturdy box type framing and ring oiling bearings.



Above: (Open-side) Calenders with new Sandy Hill designed anti-friction bearings and pneumatic load and lift.



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"Selective" and Corner Drives
Fourdrinier Paper Machines
"Packer" Screens

Castings
Bleaching Equipment
Scofield Felt Conditioners
Cleveland Type Bearings
Shaker Screens

MR. MORTENSON: Then we can say that what we have will be corrected some time if certain things are done by industry, if certain steps are taken. For the minutes, however, this statement in the minutes of our first meeting, now under discussion, will be qualified by what industry does.

MR. ROSCH: I don't think Mr. Hogan has changed anything. What he has said now doesn't alter the statement made in the previous meeting one iota and the statement as written lines up with the National Electric Code. Corrections are being made by IPCEA to rubber cable specifications at the present moment. I don't think this statement (under discussion) should be changed.

MR. HOGAN: The point is that the statement in there is not true. In the past on rubber-insulated cable, nonshielded cables have been more commonly used. Shielding will be used from now on if IPCEA recommendations and industry practices are followed.

MR. ROSCH: That is what this says. (Referring to previous minutes.) Nonshielded is what the industry is furnishing. Do you believe, Mr. Mortenson, that paper mill electricians know anything about shielded cable?

MR. MORTENSON: Yes, I do.

MR. ROSCH: In other words, if an electrician was dealing with cables he would know what to do with shielded cables?

MR. MORTENSON: Yes, I believe that is true today in our industry.

MR. ROSCH: That is surprising to me. Shielded cable has been a mystery to most electricians and contractors. When electricians had lead-covered cable to install they knew how to handle the lead. Now that lead is not used so extensively and is being replaced by shielded cable the electricians do not know how to treat the shield.

MR. MORTENSON: That, no doubt, is true in many cases but I can answer from experience. We have had unfortunate occurrences due to lack of knowledge which resulted in improper terminations and blowups. Today, however, due to the fact that we have learned through bitter experience, all of our people do know and understand and will not be fooled any more. They will not now overlook the fact that they are handling shielded cables when they are handling them and I believe that is true for the paper industry generally.

MR. ROSCH: Again, I say I'm surprised. I want to say one thing more. These statements that are here in the minutes of the first meeting have been incorporated in the latest edition of the Electric Code. On nonmetallic shielding the code specifies handling in Article 710, Sections 7117 and 7118, which goes to prove the statement of Mr. Hogan (in the previous minutes) true. This is the 1947 code (NEC book in hand) and yet in spite of the fact that it has been in effect for four years not a single person operating under National Electrical Code finds it practicable to use shielded cable. Electrical contractors, in general, do not know what this is or how to use it. Furthermore, single-conductor shielding must be of an approved type. Because of the general ignorance as to the purpose of shielding and method of handling the underwriters have not enforced the code requirements. You paper people may understand, but by and large a very few people understand this term shielded. I do not want something to be recommended to the group that might not yield good results.

MR. DAVIS: I understand this is a joint committee between IPECA and TAPPI. Recommendations that come from this committee will be joint recommendations and whatever is finally decided upon will be referred back to IPCEA for discussion. So that any discussion that we have here, the IPCEA members (Hogan is one, I don't know whether he has been notified yet, but he is now an IPCEA member) will have a chance to thrash it out. All recommendations of this group will be discussed in the full IPCEA group so that all manufacturers will have a word. The shielded above 3000 is now a standard recommendation of IPCEA. It is a standard recommendation which all may obtain from specifications of all manufacturers. Nonshielded is standard practice up to 3000. It also was brought out at an EEI (Edison Electric Institute) meeting in Detroit that all utilities were very strong in that long lengths would have to be shielded cables. The change that is referred to, brought about from all manufacturers, was not drawn out of air from one or two, and I think that matter of shielding is rather important to pulp and paper industries. When this committee gets through we should take a rather definite stand where shielding is to be used. The underwriters' recommendations are about 2000.

MR. MORTENSON: Gentlemen, when we get into the analysis of the results obtained from the questionnaires that is going to jell into a few types of insulation.

MR. DAVIS: Manufacturers hope for that too. The paper and pulp industry must give the manufacturers the right conditions. Otherwise, the manufacturer is in the doghouse if anything goes wrong. We would like to find the number of types limited, rather than a wide range of service.

MR. ROSCH: One more thing. I don't like to see loose terms used. When we speak about rubber I want it thoroughly understood that GRS rubber is the type under consideration. It will not be natural rubber. And furthermore, under government restrictions you can't use natural rubber. Therefore, we should concern ourselves with GRS.

MR. ZINK: I think butyl rubber should be used and GRS.

MR. MORTENSON: I think that we should come to the question just raised by Mr. Rosch a little later. Is there anything further to be said on the question of Mr. Hogan's statement as reported in the minutes of the last meeting?

MR. ROSCH: Does Mr. Hogan agree that I am right about the code? The code specifies shielding above 2000 volts.

MR. HOGAN: Nonshielded up to 5000.

MR. ROSCH: Semiconducting tape shielding. I am sorry we do not have a copy of the latest edition of the National Code. I would like to read you gentlemen the exact code.

(Book is produced and Mr. Rosch reads Sections 7117 and 7118, Article 710, of the National Electrical Code, 1951 Edition.)

7117. *Shielding of Rubber-Insulated Conductors.* If nonleaded, fibrous-covered, rubber-insulated conductors for permanent installation operate at voltages higher than those indicated in the following table and under the conditions mentioned, they shall be of a type having metallic or semiconducting shielding for the purpose of confining their dielectric field. The semiconducting shield shall be an approved type.

Method of installation	*Voltage in kv above which shielding is required* Neutral grounded	Neutral ungrounded
In ducts or metal conduits in wet or damp locations	2	2
In ducts or metal conduits in permanently dry locations	6[a]	3[a]
On insulators, only if multiple conductor	6	3

[a] Supposedly dry metallic conduits in some cases may contain sufficient moisture to allow formation of ozone and thus damage nonshielded cable at voltages above 2000. For conservative practice it may be desirable to shield below the limits given.

This rule is necessary because of the susceptibility to damage of rubber-covered conductors by corona which occurs at the higher voltages, particularly under alternatively moist and dry conditions.

7118. *Grounding of Shielding.* The shielding of shielded cable, whether of the metallic or semiconducting type, shall be grounded, preferably at two or more points. Stress cones shall be made at all terminations of shielding, as in potheads and joints.

Ungrounded shielding normally has a potential above ground and should be regarded as a live conductor.

MR. ROSCH: Those sections are important. Anything above 3 kv. should be shielded.

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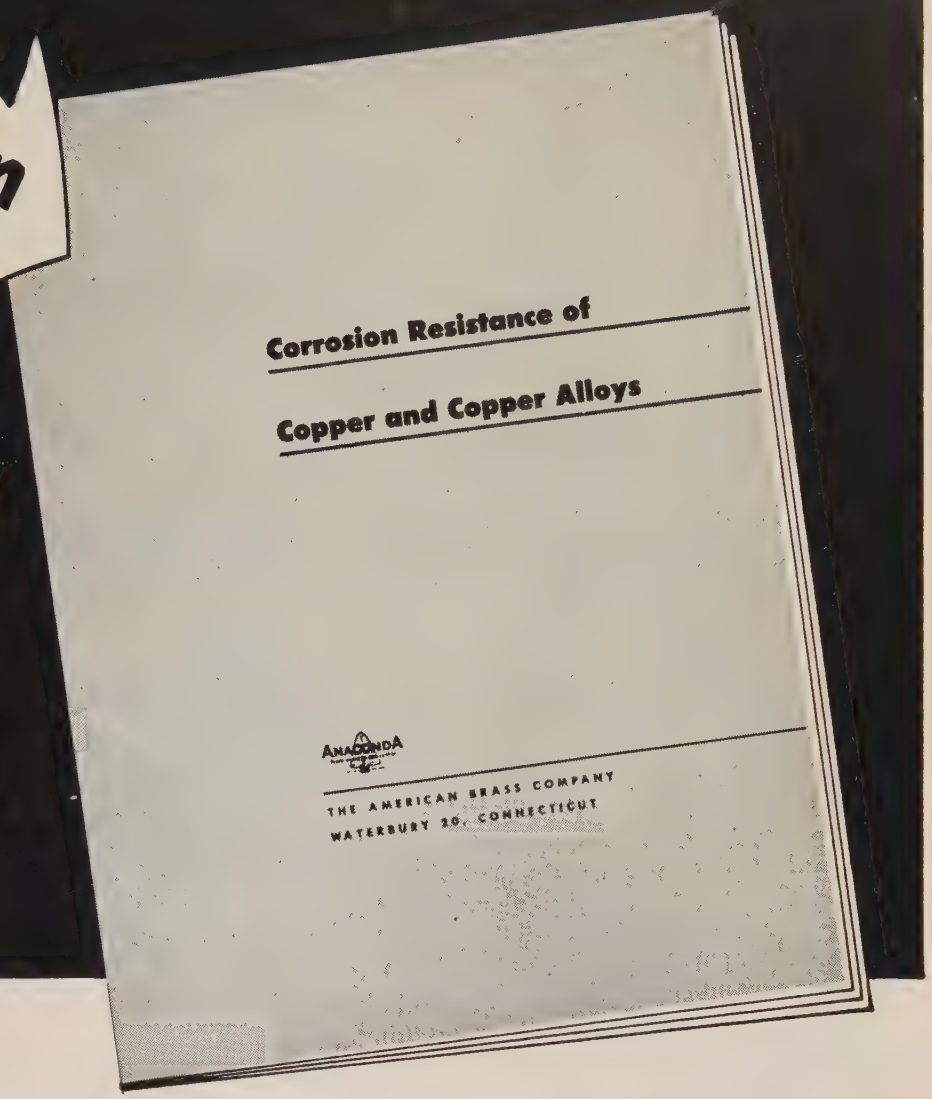

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Mr. Zink: The National Electric Code is a rule and a rule that comes under the underwriters. Whereas, IPCEA is simply a recommendation. In other words, I suppose you, Mr. Mortenson, are not subject to code inspection. You are, however, open to IPCEA recommendation.

Mr. Mortenson: That's right.

Mr. Rosch: I said this; that it has been recognized but not used.

Mr. Mortenson: Anything further? Any other errors or omissions that anyone of you gentlemen present at the last meeting can suggest? If we hear no further suggestions as to errors and/or corrections we will declare these minutes (minutes of last meeting in hand) approved, with the corrections as noted with respect to Mr. Hogan's reported statement on page 3. And we now, hearing no further objection, declare them approved.

I had intended to present Mr. Davis' letter advising of IPCEA appointments but I have already said that TAPPI is very thankful to IPCEA for what it has done.

Mr. Davis: IPCEA is also pleased that you gave your TAPPI Project our number 369. It makes for easier filing. I know, Mr. Mortenson, that your secretary files things right so you probably do not have any trouble but that doesn't always go for us.

Mr. Mortenson: We thought that IPCEA had just followed suit and numbered your Project to conform with TAPPI's.

Mr. Davis: No, we hadn't.

Mr. Rosch: It was just a coincidence.

Mr. Mortenson: I want to inject into the record that we have received a nice pat on the back from the Secretary of the General Engineering Division of TAPPI, a man who had very much to do with the organization of the Engineering Division, "Bumps" Hemphill of Johns-Manville. In writing on July 9 he said this, among other things:

"Have just completed reading the minutes of TAPPI Subcommittee on Cables and want to congratulate you and your committee on the excellent start that has been made. I am certain that much useful data will be developed as a result of this combined effort."

At this time I think I should introduce to you Ray Foster in his capacity as Chairman of the Electrical Engineering Committee of TAPPI, of which this Committee that I am heading is a Subcommittee. Ray!

Mr. Foster: We certainly think you are doing a fine job of this. I believe I am here today to keep the attendance from numbering thirteen persons. Seriously, Mr. Mortenson, you are off to a good start.

Mr. Davis: Nowhere is d.c. involved?

Mr. Mortenson: Yes, considerably.

Mr. Davis: What voltage?

Mr. Mortenson: Up to 600.

Mr. Davis: Heavy load?

Mr. Mortenson: Quite.

Mr. Zink: Magnetic separators? I am a little out of date in this paper business. When I was younger I was a maintenance engineer in a paper mill and we had d. c. headaches, particularly with the separators used throughout the mill.

Mr. Rosch: How about control circuits?

Mr. Mortenson: No, more a.c.

Mr. Davis: Some d.c?

Mr. Mortenson: Yes, some on the drive. Of course that makes up a large part of the electrical installation.

Mr. Foster: Plants having chlorine involve heavy d.c.

Mr. Davis: That will oblige us to recommend for both a.c. and d.c. Any intercommunication circuits involved?

Mr. Mortenson: Well, I think so. But, thinking of our setup here only I would have to answer no. We buy that service, but I presume some northern mills still own such systems. It has been a long time since I have been in the north. Cannot answer for their practices now. Such service can be bought for a very nominal price from the telephone company. I do think that intercommunication systems are not too general in the pulp and paper industry.

Mr. Davis: Not something that TAPPI is interested in?

Mr. Mortenson: That's right, it isn't.

Mr. Davis: Fixed cable? Portable cable?

Mr. Mortenson: I would say yes. However, our questionnaire did not cover portable cables. In response to the questionnaire, though, much was made of portable cable.

Mr. Zink: Do you use portable cable on wood yard cranes?

Mr. Mortenson: Yes, and in several other places.

Mr. Rosch: I think the quickest way of getting somewhere is by trying to reduce the number of types of cables and itemize them down here.

(Mr. Rosch indicates method on pad.)

The different types of insulations you put across over here and when we agree on something we put an X in the proper intersecting space. Eventually we could see the X's. We could then combine them and discover the trend.

Mr. Mortenson: Just wonder if this does not do it more or less.

(Mr. Mortensen presents questionnaire summary sheets.)

Mr. Zink: Do you get what Mr. Rosch is driving at?

Mr. Mortenson: Not quite.

Mr. Smith: We intend to go ahead and complete the summary sheets to summarize the various types of cable used for the various services in the different departments.

Mr. Rosch: You can get a fair picture that way.

Mr. Mortenson: Can you set that up now, Mr. Rosch? Lead off with what you have in mind and set the thing up on the blackboard so the gentlemen can see you write as you talk.

Mr. Rosch: All right.

(Mr. Rosch outlines the pattern he thinks best to follow.)

Mr. Rosch (Demonstrating on blackboard): Probably these are not classifications to be used. Over here to be type of service. If these need further refining we could go ahead and give it that.

Mr. Mortenson: How about motor leads, lighting, motor control leads, etc.?

Mr. Rosch: You know service conditions much better than I do.

Mr. Davis: I think we want more information, then, on what we should recommend.

Mr. Zink: That is a rather sizable piece of work.

Mr. Davis: I think it is the case of manufacturers being ignorant of conditions and the paper people being ignorant of cable types.

Mr. Mortenson: Gentlemen, under the circumstances, it might be well to hold Mr. Rosch's suggestion in abeyance for just a short time until we take a look at what the boys in the paper industry say from experience is the best to use in the various departments. We will take a quick look and then come back to Mr. Rosch's contention.

Gentlemen, the press of many things has made us a little late in getting the tabulating done. It has been a bit more of a chore than we anticipated. So much so that my good wife remarked, after we had worked until 5 o'clock one morning and 3 the next morning on this tabulating business and were working the next evening late: "My heavens, Al, you're going to be the slap happy pappy of TAPPI."

Smitty and I worked out percentages and recorded every bit of data just as accurately as we could. I will now give you each a copy of the sheets Miss Miller typed up this morning that perhaps you can use for tabulating purposes.

(Mr. Mortenson passes out sheets listing common causes of cable failure and predominant location of above failures.)

Of course all of this that you get today you will get in final typed legible form that will be easy to see and study.

Due to the fact that many of those who replied told us so much more than we wanted to know we had difficulty recording it. They went almost too far in cooperating with us and

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With simple design, simple operation, the Conkey Integral Self-Supporting Evaporator makes big savings wherever it is installed. Each effect of the evaporator combines in a cylindrical pressure vessel all these elements: a vapor body—centrifugal entrainment separator—heating element—condensate flash chamber and a supporting skirt. All structural supports are eliminated. Foundation is a simple slab footing.

The new Conkey Integral Evaporator is shipped fully assembled and a single up-ending operation sets it in place. Its vertical positioning saves floor or ground space, and where weather conditions permit, the entire unit may be installed outdoors. No housing is needed except for pumps and instruments.

Because its design reduces pressure drop losses between effects, the Conkey provides an increased working temperature drop across the heating element surface. Result: a net positive gain in evaporation—extra evaporating capacity. For complete technical information, write for Evaporator Bulletin.

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gave us a tremendous amount of information. So we had to get out an extra sheet. We suggested 3 predominant locations of cable failure, they ran 15. On causes of cable failure we suggest 15, they threw in many others. So much for that.

We come now to the tabulation of the data we received from the *sulphate pulping industry.* I thought these sheets would apply to what we are going to talk about now, but they don't—they apply to this bottom sheet of the questionnaire, causes of failure. Perhaps you gentlemen should use the yellow pads placed before you for tabulation of the information I am now about to give you. Head this sheet, *Sulphate Industry,* Type of Cable. This will be given you percentagewise and industry-wide and will be gleaned from what the body in the paper industry say is best from experience.

MR. DAVIS: How many replies did you have?

MR. MORTENSON: We had approximately 20% of the 833 mills circularized. *Groundwood*—there were 293 industry-wide answers to the various questions put to *Groundwood.* Out of 293, they say natural rubber neoprene sheath across the board to the extent of 15.6%. Synthetic rubber neoprene cover across the board, they say 14.7%.

MR. SMITH: All rooms included.

MR. MORTENSON: Okay, here we go. For natural rubber braid neoprene 0.68%, synthetic rubber braid 4.8%, natural rubber lead 16%, synthetic rubber lead 0%, varnished cambric lead 1.36%, varnished cambric braid 12.7%, asbestos varnished cambric 1.02%, thermoplastic 32.4%, weatherproof 0.342%, aerial self supporting 0%, bus copper generator leads 0.342%.

Out of the *questions* put to the *sulphate industry* 1900 answers came back. Out of the 1900 answers 671 said natural rubber neoprene cover for 35.3%, 328 said synthetic rubber neoprene cover for 17.24%, 163 answers said natural rubber braid for 8.58%, 18 said synthetic rubber braid for 0.96%, 13 said natural rubber lead for 0.69%, and there was not 1 who wanted synthetic rubber lead. 103 said varnished cambric lead for 5.42%, 215 said varnished cambric braid for 11.32%, 82 said asbestos varnished cambric for 4.32%, 226 said thermoplastic for 11.9%, 2 said weatherproof for 0.15%, 54 said aerial self supporting for 2.85%, 24 said bus duct for 1.26%. We have thrown bus duct and AVC lead together. There is a great difference in sulphate and groundwood on thermoplastic.

MR. GRAHAM: Lots of replies. This is an interesting analysis. One question, if you were to buy cable for application here, Mr. Mortenson, you would simply specify RL or RHL. Is that what you would ask for? How would you know if it were synthetic or natural rubber?

MR. MORTENSON: We would have to ask questions of the vendor.

MR. ZINK: I am glad you brought that up. I was going to ask how far back this might go. Are they using these types now or do they go back before the war?

MR. MORTENSON: They go back many years. Some have reported that they have had no failures for 25 or 30 years.

MR. ROSCH: That paints a different picture.

MR. GRAHAM: 671 still think when they order that they get natural rubber insulation when they might be getting synthetic.

MR. SMITH: They are exercising a preference for what they are getting.

MR. ROSCH: Will sulphite be different?

MR. MORTENSON: Yes. We are coming to it now. Here we have 1508 replies: answers to *questions* contained in the *sulphite* questionnaire. Industry-wide across the board 205 of them go for natural rubber neoprene for 13.6%, 73 say synthetic rubber neoprene, 4.85%; 438 say natural rubber braid, 29.1%; 25 say synthetic rubber braid, 1.66%; 13 say natural rubber lead, 0.86%; none of them say synthetic rubber lead, 0%; 159 say varnished cambric lead, 10.5%; 215 say varnished cambric braid, 14.3%; 118 say asbestos varnished cambric, 7.83%; 195 say thermoplastic, 12.9%; 12 say weatherproof, 0.80%; 1 says aerial self supporting, 0.06%; 36 go for paper-insulated lead cover for 2.39%; 18 for bus duct, 1.19% in dry locations. In sulphite they go for it more than just for generator leads.

MR. DAVIS: This is very, very good. It can be made into a composite picture right now.

MR. MORTENSON: Let's take *waste paper.* 319 answers with 4 for natural rubber neoprene for 1.25%, 0 went for synthetic rubber neoprene for 0%; 109 say natural rubber braid, 34.2%; 31 say synthetic rubber braid, 9.73%; 18 go for natural rubber lead, 5.65%; 0 synthetic rubber lead for 0%; 18 varnished cambric lead, 5.65%; 30 varnished cambric braid, 12.2%; 25 asbestos varnished cambric, 7.83%; 69 thermoplastic, 21.-62%; AVC lead and bus duct 6, or for that, 1.87%.

Now here we come to *rags.* 572 answers with natural rubber neoprene 0 answers with 0%, synthetic rubber neoprene 37 replies with 6.46%, 258 natural rubber braid, 45.1%; 20 synthetic rubber braid, 3.5%; 12 natural rubber lead, 2.1%; zero synthetic rubber lead, 0%; 47 varnished cambric lead, 8.21%; 22 varnished cambric braid, 3.85%; 76 asbestos varnished cambric, 13.2%; 79 thermoplastic, 13.8%; 0 for weatherproof, 0%; 0 aerial self supporting, 0%; bus duct 21 for 3.67%.

Here we come to *others.* This is everything we could not classify and place in a given branch of the industry. However, it is just as authentic as it would be if it could be broken down in the various branches because it gives authentic information on what insulations are best to use in every room of every branch of the industry. Ready? Here we go.

For *others* 1826 answers. 454 of those answers said natural rubber neoprene across the board for 24.82%; 127 synthetic rubber neoprene, 6.95%; 507 natural rubber braid, 27.8%; 47 synthetic rubber braid, 2.58%; 68 natural rubber lead, 3.72%; 0 synthetic rubber lead, 0%; 36 varnished cambric lead, 1.97%; 90 varnished cambric braid, 4.93%; 120 AVC, 6.57%; 278 thermoplastic, 15.22%; 20 weatherproof, 1.1%; 18 aerial self supporting, 1.00%; 60 paper and lead, bus exposed and bus duct, that is 3.28%.

MR. MORTENSON: Can you detect any pattern or any similarity, much, between industries?

MR. ROSCH: I can see no rhyme or reason.

MR. MORTENSON: We can break this down further. What I have given you isn't a true picture, perhaps. We haven't carried the tabulating and recording as far as we can because we haven't had the time. But we intend to do it and when we do we will have irrefutable figures. When we set the various rooms and departments in every branch of the pulp and paper industry off against the type of insulation found from experience to be best in each and every case, room and application, as we can, with the wealth of information gathered, we will have a picture as true as can be made. A picture, I think, that will enable TAPPI to intelligently ask IPCEA for specs to cover and in turn enable IPECA to meet the request without difficulty.

MR. SMITH: I think the general trend is pretty well shown already; but what we intend to do further will, without doubt, point the way more clearly.

MR. MORTENSON: We will have a percentage figure in every block on these sheets.

(Mr. Mortenson refers to questionnaire summary sheets.)

DR. STURDEVANT: Have you done that on one sheet?

MR. MORTENSON: No, we have not yet.

MR. ROSCH: To find an industry where base liquids are used in the manufacturing process giving such acclaim to lead is most surprising. Lead is not impervious to alkalis. It breaks down very readily in the presence of alkali. Apparently the paper boys don't know the characteristics of lead.

DR. STURDEVANT: Maybe they do not use it in the departments where alkali is present.

MR. MORTENSON: That's right. It is used in the power plant and the paper machine room and other places that are free of alkaline liquor.

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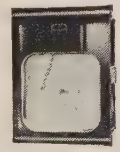

THE DEPENDABLE GUIDEPOST OF INDUSTRY

BRISTOL

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

MR. HOGAN: Out of the total number of paper companies sent these surveys how many have replied; what per cent?

MR. MORTENSON: Approximately 20%.

MR. DAVIS: 20% of the industry?

MR. MORTENSON: Yes. We sent out 833 questionnaires, and we have more than 150 replies back already. The questionnaires went to every paper company on the North American Continent. Was surprised that we received as many replies as we did. We expected 10%, which is about average. I think our success in doubling the average was due to our making the replies easy to get out. Merely necessary to read and check. It was not necessary to do too much writing. As I say, we got about 20%.

MR. ZINK: I think such a good return indicates wonderful interest.

MR. GRAHAM: Now, just how did you work this? Take for instance the Brown Paper Mills, did you send a questionnaire to more than one person in that company?

MR. MORTENSON: Yes, but we sent to only a single individual in each of their mills. It was the mills that we wanted to get, not so much the companies. There are not 833 pulp and/or paper companies on the continent. But there are 833 mills, and a questionnaire went to each mill.

MR. GRAHAM: Were any engineering firms included?

MR. MORTENSON: Just one engineering firm, Chas. T. Main, Inc. Let us take a look now at how the failures have occurred in the mills heard from and where they occurred; and it is for the purpose of recording this dope that the sheets, mistakenly handed out this morning, were given you.

MR. MORTENSON: What do you say?

MR. ROSCH: We could use what you have given us as a key sheet and put on another piece of paper beside it with just the numerical designation on it and use that for recording the percentages I expect you are about to give us. Then we could get a little glue and piece the two together.

MR. MORTENSON: Your suggestion is well taken, Mr. Rosch. So, gentlemen, if you will fix up your sheets, we will proceed when you are ready.

MR. ROSCH: Put that in the record, Miss Miller, that I suggested something good.

KEY SHEET

B. Common Causes of Cable Failure (Normal Operating Conditions)

1. Physical damage to insulation during installation
1a. Nonobservance of recommended cable bending radii
1b. Not careful in making up cable stresscones, potheads, etc. Overload
1c. Steam or other high-temperature pipes too close to cable ducts
Soldered lugs and solderless connectors
2. Deterioration of cable insulation due to age
2a. Deterioration of cable insulation due to oxidation
3. Imperfection in insulation during manufacture
4. Presence of moisture in cable
5. Deterioration of cable due to exposure to oil
6. Deterioration of cable due to exposure to acids
7. Deterioration of cable due to exposure to alkali
8. Deterioration of cable due to exposure to ozone
9. Deterioration of cable due to exposure to sunlight
10. Deterioration of cable due to exposure to rats biting lead
10a. Deterioration of cable due to exposure to condensate in conduit
10b. Deterioration of cable due to exposure to heat
10c. Deterioration of cable due to exposure to vibration at junction box
11. Deterioration of cable due to exposure to water
12. Corrosion of lead sheath due to electrolysis
13. Corrosion of lead sheath due to chemical reaction
14. Improper cable termination
15. Improper cable splicing
16. Connector failure
17. Obstruction in conduit
18. Physical damage after installation
19. Lightning

C. Predominant Location of Above Failures

1. Cable terminations
2. Splices
3. Cable bends
3a. Cable bends—physical damage during installation
4. Condulets
4a. Acid
4b. Presence of moisture, from condensation, has caused many failures where conduit runs from inside the building to location outside the building
5. Junction boxes and LB's due to penetration of insulation by cover screws
6. In conduits
7. Improper bushing termination in runs to switches and starters
8. Conduit fittings with covers missing permitting moisture and other matter to enter and damage the cable at that point
9. Underground
10. Arc of insulators on overhead lines (saltcake and water)
11. Conduit not pitched to drain and plugged to prevent condensation from cross circulation
12. Low point of run where water settles
13. General
14. No particular location
15. Long cable runs

MR. MORTENSON: All set? All right—causes of failure, *Sulphite Industry.*

1.	7.4%	6.	7.4	12.	2.12
1a.	0	7.	5.3	13.	1.06
1b.	4.25	8.	1.06	14.	6.4
1c.	2.12	9.	2.12	15.	6.4
2.	15.95	10.	2.12	16.	1.06
2a.	5.3	10a.	1.06	17.	0
3.	0	10b.	1.06	18.	0
4.	17	10c.	1.06	19.	0
5.	6.4	11.	3.18		

MR. MORTENSON: *Sulphate* now.

1.	16.2%	6.	5	11.	1.25
1a.	6.25	7.	7.5	12.	3.75
1b.	3.75	8.	0	13.	3.75
1c.	1.25	9.	1.25	14.	3.75
2.	10.	10.	0	15.	2.5
2a.	0	10a.	1.25	16.	0
3.	1.25	10b.	5	17.	1.25
4.	12.5	10c.	1.25	18.	1.25
5	10			19.	0

MR. MORTENSON: That's it. Now *Groundwood.*

1.	25%	6.	0	12.	0
1a.	0	7.	0	13.	0
1b.	0	8.	0	14.	8.3
1c.	0	9.	8.3	15.	8.3
2.	25	10.	0	16.	0
2a.	0	10a.	0	17.	0
3.	0	10b.	0	18.	0
4.	16.7	10c.	0	19.	0
5.	8.3	11.	0		

MR. MORTENSON: Now *Rag.*

1.	9.55%	6.	0	12.	0
1a.	0	7.	4.77	13.	0
1b.	0	8.	0	14.	0
1c.	0	9.	0	15.	4.77
2.	28.6	10.	0	16.	0
2a.	14.3	10a.	4.77	17.	0
3.	0	10b.	0	18.	4.77
4.	19.2	10c.	0	19.	0
5.	9.55	11.	0		

MR. MORTENSON: Here we come to *Waste Paper.*

1.	13.8%	6.	6.9	12.	3.5
1a.	6.9	7.	0	13.	6.9
1b.	3.5	8.	0	14.	3.5
1c.	0	9.	0	15.	3.5
2.	17.2	10.	0	16.	0
2a.	3.5	10a.	0	17.	0
3.	0	10b.	0	18.	3.5
4.	10.5	10c.	0	19.	0
5.	13.8	11.	3.5		

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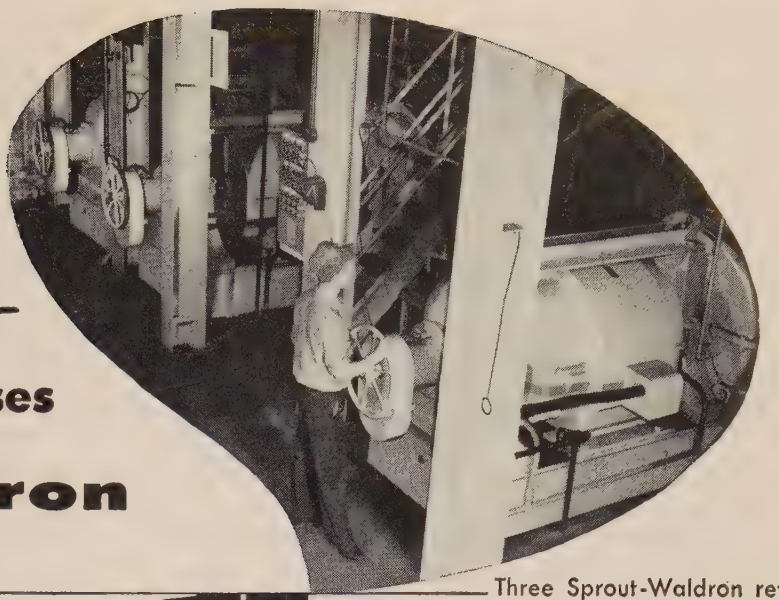

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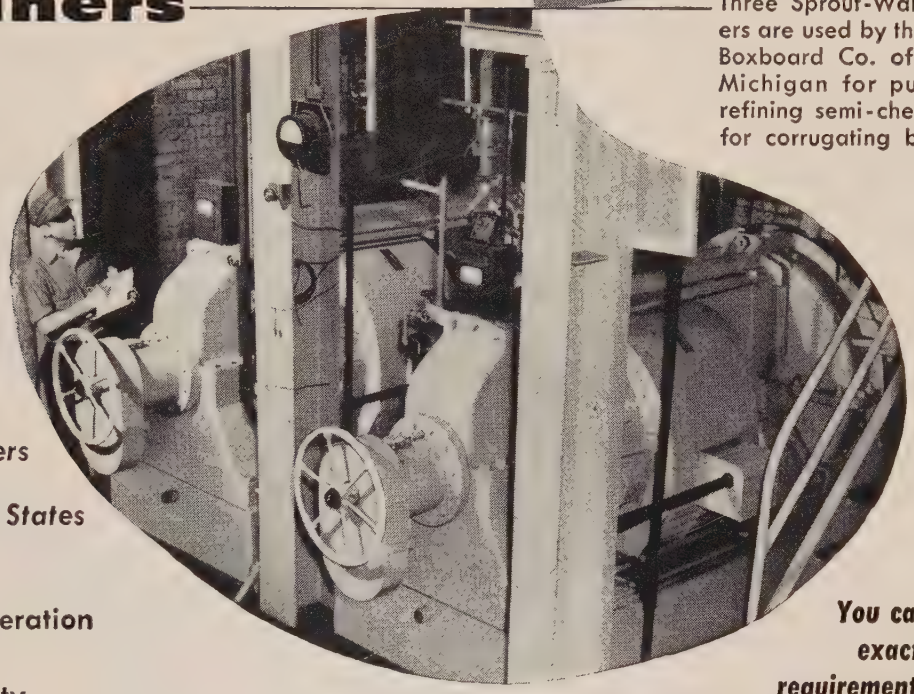

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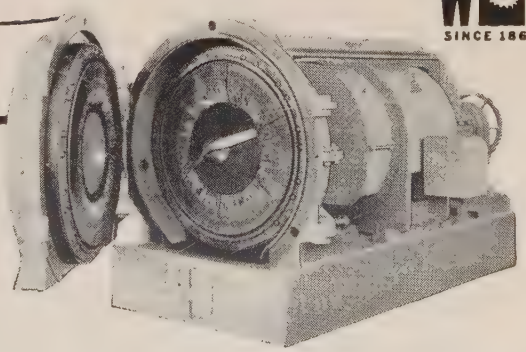

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170

MR. MORTENSON: That's it. Now we come to *Others.*

1.	11.75%	6.	3.92	12.	3.26
1a.	0.655	7.	2.61	13.	0.655
1b.	0	8.	0	14.	7.2
1c.	0	9.	0.655	15.	3.92
2.	18.3	10.	0	16.	0
2a.	5.23	10a.	1.3	17.	0
3.	1.3	10b.	3.26	18.	1.3
4.	17.6	10c.	1.3	19.	1.3
5.	10.45	11.	4.57		

MR. MORTENSON: Now we come to where it happened.

MR. DAVIS: That is based on how many replies?

MR. MORTENSON: In *sulphite* there were 94 failures reported in all, in *sulphate* 80 failures were reported in all, *groundwood* 12, *rag* 21, *waste paper* 29, and *others* 153.

MR. DAVIS: Over any particular period of time?

MR. MORTENSON: No.

MR. MORTENSON: Now for the predominant location of cable failures, *Sulphite.*

1.	28%	4b.	4	10.	0
2.	24	5.	4	11.	0
3.	12	6.	8	12.	0
3a.	4	7.	4	13.	0
4.	4	8.	4	14.	0
4a.	4	9.	0	15.	0

MR. MORTENSON: Failure locations, *Sulphate Industry.*

1.	21.2%	4b.	0	10.	3.03
2.	24.2	5.	9.1	11.	0
3.	27.2	6.	6.06	12.	0
3a.	0	7.	0	13.	0
4.	1.03	8.	3.03	14.	0
4a.	0	9.	3.03	15.	0

MR. MORTENSON: All right, *Groundwood.*

1.	28.6%	4b.	0	10.	0
2.	43.0	5.	14.3	11.	0
3.	0	6.	14.3	12.	0
3a.	0	7.	0	13.	0
4.	0	8.	0	14.	0
4a.	0	9.	0	15.	0

MR. MORTENSON: Here we go on *Rag.*

1.	22.2%	4b.	0	10.	0
2.	22.2	5.	11.1	11.	0
3.	33.3	6.	11.1	12.	0
3a.	0	7.	0	13.	0
4.	0	8.	0	14.	0
4a.	0	9.	0	15.	0

MR. MORTENSON: Okay, here we have *Waste Paper.*

1.	33.3%	4b.	0	10.	0
2.	33.3	5.	0	11.	16.7
3.	16.7	6.	0	12.	0
3a.	0	7.	0	13.	0
4.	0	8.	0	14.	0
4a.	0	9.	0	15.	0

MR. MORTENSON: Now, *Others.*

1.	32.0%	4b.	0	10.	0
2.	14.0	5.	10	11.	0
3.	14.0	6.	6	12.	2.0
3a.	0	7.	0	13.	1.6
4.	0	8.	0	14.	4
4a.	0	9.	0	15.	2

MR. MORTENSON: Now let me read these notes. We won't, in our report, disclose the name of any company. However, in that this gathering here is all in the family, I will mention names. A company says this:

> "Have had *no failures* in 15 years and have used natural rubber insulation with neoprene covering, thermoplastic, natural rubber with braid (for motor leads, motor control, and lighting) and synthetic rubberlike insulation with neoprene covering, weatherproof, and thermoplastic insulation, for prime and subfeeders."

MR. MORTENSON: And this from another company:

> "Have had *failures* due to improper cable terminations but say this happens predominatey on low-voltage small wiring. Infrequently on large feeders."

MR. MORTENSON: I have a note here to read this particular company's letter in its entirety. Would not have put that in if it were not important reading. So here we go.

> "In accordance with your request, we enclose one copy of the check questionnaire on application of electric cable to the paper industry as applied in our particular plant.
>
> "It is very difficult, as you realize, to present a true and complete picture on such a complicated subject with all of the variable operating conditions involved. In general, however, we believe we can make the following statements:
>
> "1. On major items of equipment demanding uninterrupted availability, we specify NRIN-SCE and NRIN-SCU at all voltages.
> "2. For prime feeders, we specify AS installations, provided the conductor size is not above 500,000 CM since it becomes too difficult to handle above this weight with likelihood of physical damage to the cable during installation.
> "3. We do not apply TP extensively above No. 4 wire size because we have found a tendency for the insulation to deform under the pressure of the copper conductors on bends in the larger sizes.
> "4. We have found TP-SCE to be exceedingly satisfactory for lighting installations and many control lines because of its small diameter and smaller conduit sizes required. We also favor this installation on temporary or short duration installations because of its first cost and also in existing conduit installations where copper size must be increased."

MR. MORTENSON: That same company says they find natural rubber with neoprene jacket fails because of physical damage during installation, that natural rubber braided *fails* due to deterioration of insulation due to age, that high-voltage cables only (75,000) *fail* because of presence of moisture in the cable and that *failures* occur in cable terminations under No. 4 and in cable bends under No. 1.

MR. MORTENSON: Another company has this to say:

> "Have discontinued the use of lead cable because of corrosion of lead sheath due to electrolysis. Majority of *failures* due to chafing in pull boxes due to vibration or concentration of weight or pressure at a spot. Now use fiber sheeting in boxes and mouths of conduits."

Floods and physical damage due to structural changes mentioned by one company, in rag category as cause of damage. and still another reports 25 to 35 years' cable life using natural rubber braided for motor leads, motor controls, and lighting, and natural rubber leaded and varnished cambric leaded for prime and subfeeders and natural rubber braided for generator leads.

Here's an outfit collaborating with you, Mr. Rosch, on lead cable.

Several companies say $^3/_4$-inch conduit should be the smallest used, that anything smaller should be outlawed.

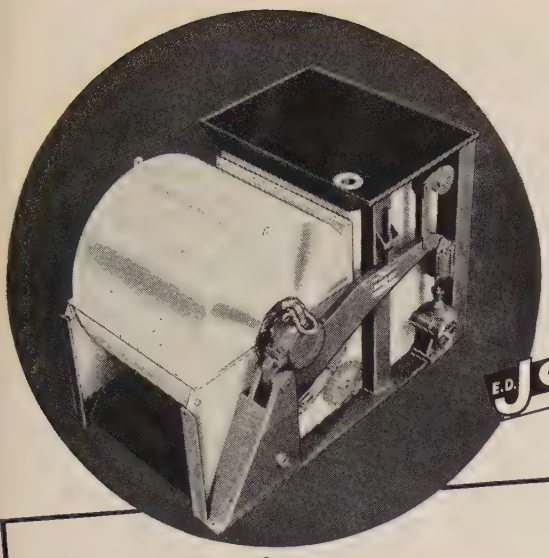
MR. DAVIS: And at the same time some are asking for $^3/_8$ inch now.

MR. ROSCH: It is now 10 minutes to one, about 3 o'clock in Boston. Don't you think we'd better quit for a while to eat and refresh ourselves. Mr. Mortenson, where do you get all your energy?

MR. MORTENSON: Gentlemen, please, while I am giving you what we have gotten from the questionnaire let me give you the balance. We haven't too much more. We are just about done. What I will now give you has been gleaned from the questionnaires as we recorded the type of insulation used and preferred. There are some off-side remarks that contain a lot of meat and should be injected into the record. I have put down company names, but none of the names shall ever be publicly disclosed. However, we give it all to you so you will know that it is all authentic. All of our records and papers will eventually go into the archives of TAPPI where they can be perused, upon request, for verification of any points or statements we might make.

One paper company has this to say:

> "Thermal plastic—all offices and general plant buildings. Natural rubber all departments. Subfeeders where temperature does not exceed 140°F. Natural rubber multiple conduc-



NOW — get up to 65% power savings with this pre-assembled BEATING UNIT

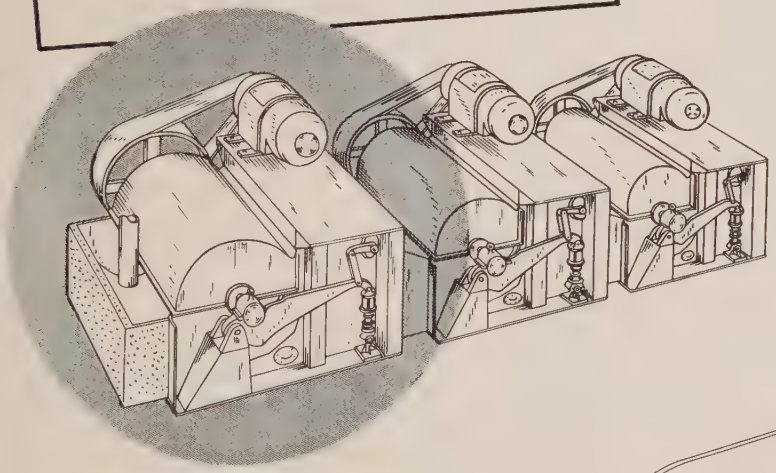
(*Pat. applied for*)

- More refining capacity — up to twice as much as any similar machine
- Positive control of roll pressures — no possibility of untreated stock passing through unit
- Greater flexibility of operation
- Fully automatic control
- Proved mechanical design
- Lower installation cost — no assembly in the mill
- Simpler floor construction — minimum floor loads, no shifting loads
- Requires less floor space — motor support is an integral part of the unit
- Lower maintenance — completely non-corrosive where exposed to stock

This complete, packaged Beating Unit—as simple to install as a Jordan — produces better quality, more uniformly refined fibre, at *lower cost per installed horsepower, lower cost per unit of refining capacity*, than any conventional beater.

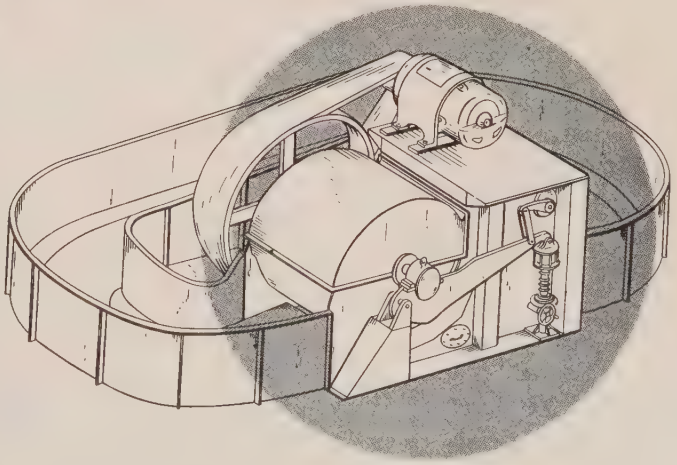
Backed by the engineering skill and experience that produced over 150 Jones-Bertrams Patent Beaters, this new unit embodies features never before incorporated in one machine . . . features of design, control and operation which can mean up to 65% power savings for you.

Write today for details, or ask your Jones representative.



MULTIBEATER *for Continuous Operation*

As shown in this illustration, the Jones Beating Unit can be installed in a Multibeater set-up for continuous operation. Positive control of re-circulation and roll-pressure on the Jones-Bertrams type rolls and bed-plates makes it impossible for untreated stock to pass through the unit. Any roll in the Multibeater may be by-passed, when desirable for any reason, without shutting down the group.



TUB INSTALLATION *for Batch Beating*

The Jones Beating Unit also offers special advantages for conventional tub installation: low installation cost — complete unit comes ready for installation with no assembly necessary at mill; floor space savings — motor support is right on the beating unit; greater rigidity and accuracy — because of the short spindle length; lower maintenance — unit is completely non-corrosive where exposed to stock.

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BUILDERS OF QUALITY STOCK PREPARATION MACHINERY

tor machine drive control, from section cubicles to operator stations or master panel. Neoprene jacket over entire cable. Rubber insulation and neoprene jacket over each conductor. Switchboard wire—asbestos varnished cambric in turbine room and machine room. Special small control boards No. 16 wire or smaller—thermal plastic—all departments—wet locations."

One company uses ventilated copper bus between generator and switchboard. And still another comes through with this information and I quote:

"Prime feeders and subfeeders paper insulated lead covered or P.I. steel armored. Portable conveyors, motor secondary leads—natural rubber neoprene-sheathed and/or asbestos varnished cambric with ground lead on retractable reels."

Still another company comes through with this:

"Prime feeders between power house and mill—bare conductors supported on steel towers. Prime feeders and generator leads synthetic rubber insulated with neoprene jacket with copper shield under the neoprene jacket."

MR. ROSCH: Can we come back to shielding for just an instant?

MR. MORTENSON: Surely.

MR. ROSCH: Shielding has farther reaching aspects than many people realize and cable manufacturers are deeply concerned. A paper clarifying the purpose of shielding and how shielded cable should be handled would be of great benefit to the pulp and paper industry, many manufacturers think.

MR. MORTENSON: We have no quarrel with the manufacturer of the cable. No complaint whatsoever. But we do complain about the way the contractor handled the stuff the cable manufacturer handed to him.

MR. ROSCH: Would you write such a paper, as I have suggested, for general publication, Mr. Mortenson? It might do a lot of good.

MR. MORTENSON: I will do it gladly just as soon as I can find time.

MR. ZINK: Mr. Rosch correctly stresses the importance of shielding. One of the reasons for this is that we are rapidly getting away from lead. And while the electricians knew and know how to handle lead they don't know how to handle the conducting and semiconducting nonmetallic sheaths or shields that have replaced it.

MR. ROSCH: Noticed when you spoke of natural rubber and lead the per cent usage was small. There is a critical shortage of lead. They tie in together. More people may have wanted to use lead but it just wasn't available.

MR. MORTENSON: I see. Now I will read something from another company which I think a bit out of the ordinary:

"Unusual application of synthetic rubber insulation neoprene sheath with interlocked armored cable."

I ask, how could this be done? I think this is quite unusual spec.

MR. ZINK: It is being done in a lot of mills. Several cable manufacturers are turning out such cable. Some chemical plants are demanding it.

MR. MORTENSON: Thanks for the enlightenment. In this instance, I was dumb. Now here is something else from the same company: "No more subfeeders in floor slab."

That is, no doubt, from someone who has had blowups due to buried lines being struck by drills and such. Other companies will not have it any other place but the slab, so they say.

MR. MORTENSON: Still another company offers this information: "Generator—unusual application of asbestos covering over transite or fiber duct exposed." Then the question comes to my mind, is this for fire protection or insulation or both? How does he do it?

Another company says: "Asbestos varnished cambric in high-temperature locations (recovery)." The choice of one more company, "Subfeeders—all departments—unitrol bus." Here we have one who states: "Prime and subfeeders 2300 volts outdoors, natural rubber neoprene jacket, 440 and 2300 volts in doors, varnished cambric braided, 13,800 volt prime feeders, varnished cambric leaded."

Another one says: "Have standardized on synthetic rubber with neoprene jacket. Everything in rigid conduit either exposed or underground."

Another offers this information—"No conduit in floor. Where it must pass through, it goes through sleeve extending well above floor. This prevents conduit from rusting off at floor line." Not what we are particularly interested in, I would say.

Another company uses natural rubber braided on lighting, run open in acid making room, sulphur burning room, and digester room. Still another uses thermal-plastic up to No. 4 for motor leads and subfeeders and natural rubber braided for larger sizes.

We find this particular company prefers conduit in or under the floor slab.

And here is one who says that galvanized iron conduits fail long before the cables they contain and usually make it necessary to replace the entire conduit. Some fail in as little as three years where moisture and corrosive chemicals are most severe. There is a definite need for a rigid cable support, they say, which will withstand these severe conditions. This company pressurizes and ventilates its bleach plant, motor, and control rooms.

MR. HOGAN: Some people are getting away from corrosion of galvanized steel conduit by putting a neoprene cover over it.

MR. MORTENSON: From one questionnaire we find a certain company uses asbestos fixture wire on lighting in hot areas.

Another company offers this information—subfeeder—part of unit substation design, copper bus enclosed in sheet steel gutter. And another—generator leads—under 25 kw. thermoplastic.

And this company, gentlemen, uses paper-insulated lead sheath for 11,000 volts incoming power, prime and subfeeders natural rubber with lead sheath for 2200 volts distribution and natural rubber and braid for 550 volts distribution.

Here is a new one. We have never bumped into this before. A company says they have standardized on Pyrotenax cable on all new installations. Cheaper, easier to install, so they say, and resistant to deterioration due to moisture. (Manufacturers are in England. Distributed by Pyrotenax Co. of Toronto, Canada.)

And here we have a company who offers—General—wet or acid conditions, Pyrotenax cable coated with clear varnish (baked) before installation.

Still another company says: "Motor controls, natural rubber braided. In bleach plant, trays carry control cables—very satisfactory."

This particular company makes rag content bonds, ledgers, onion skins, specialties. They just buy either weatherproof type or rubber covered, occasionally, in small sizes different colored plastic. Coated wire (small amounts). They state that they have a lot of such wire which has been in place over 30 years. To be perfectly frank they do not know what this wire is made of.

And from another company: "Credit given to natural rubber insulation with neoprene jacket, on basis of supporting letter, but natural rubber and braid installed in this plant in service 25 to 30 years carrying full load and sometimes in excessive of rating trouble free."

One questionnaire was filled out based on a particular company's standards but they mention several installations of thermoplastic insulated wire promising excellent results.

MR. MORTENSON: Well, gentlemen, that's the last—what the cobbler hit his wife with.

MR. ROSCH: My Gosh! He must have been a heel.

MR. MORTENSON: Now gentlemen, we will adjourn for lunch.

MR. ROSCH: I just want to say one thing before we go, Mr.

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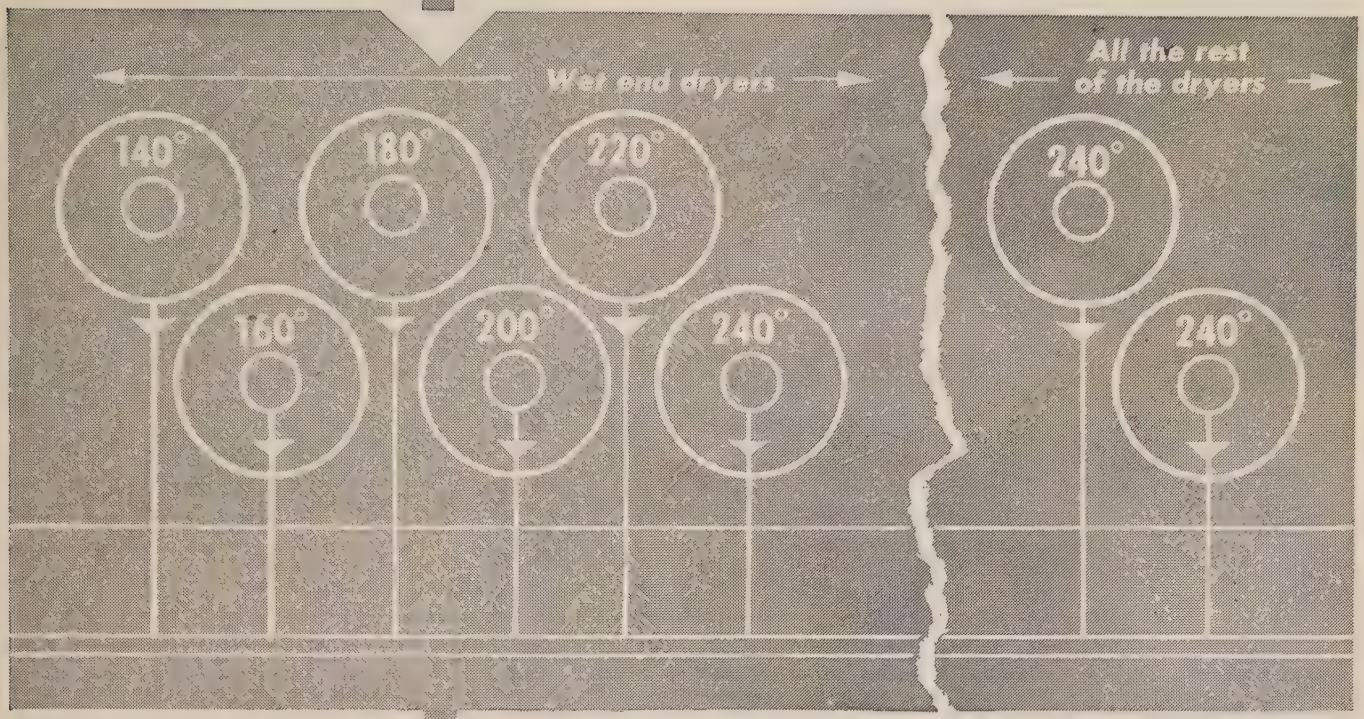

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WRITE FOR BULLETIN NO. 187 — two-color diagrams and explanation show you how the Control operates to give you accurate dryer temperature control.

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Moisture Control Systems
Individual Dryer Temperature Controls
Paper Machine Drainage Traps
Inverted Bucket Steam Traps
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Mortenson. Never in the history of my life have I been given so much information at one time as I have gathered thus far at this meeting. It astounds me and is almost unbelievable. 20% of what you have given us was as much or more than could be reasonably expected. It is a privilege and a pleasure to be in attendance here, I want to go on record as saying this.

MR. MORTENSON: I thank you sincerely, Mr. Rosch, for those kind words. And now, gentlemen, we will lunch.

1:00 P.M. Luncheon at the Harvesters Hotel, Cantonment, Fla., with Justin Weddell, Public Relations Director, St. Regis Paper Co., as guest.

2:40 P.M. Afternoon session called to order.

MR. MORTENSON: Gentlemen, we will now come back to order. Just prior to lunch we completed the individual tabulating of what had been tabulated by the members of the committee here from answers to the questionnaires. Just wonder if what you set down on the sheets you have before you shows any particular pattern so that we can determine, or get an idea at least, what the people in the industry, the pulp and paper industry, think about what is best to use where. I will now get a chance to listen.

MR. GRAHAM: Before you start listening I would like to ask one question. It might simplify matters. On this sheet entitled "Common Causes of Cable Failure" note Item 2, which reads, Deterioration of cable insulation due to age; and Item 2a, which reads, Deterioration of cable insulation due to oxidation. Are they not one and the same thing? If not, what is the difference? I notice in reviewing the questionnaires different answers have been given; but to my mind they are the same. I suggest we lump them together.

MR. MORTENSON: Just one moment, Mr. Graham. Is it the consensus that deterioration of cable insulation due to age and deterioration of cable insulation due to oxidation are one and the same thing?

MR. ROSCH: I don't usually disagree but I don't believe a lot of cables fail due to cracking, but they might fail due to hardening of the material. I don't know whether I would call the two descriptions one and the same or not. I hardly think they are. One of them is made by some of the people who wrote the answers and they were differentiating when they did it.

MR. MORTENSON: Anyone else have any other ideas? All right, Mr. Davis.

MR. DAVIS: I am in agreement with Mr. Graham. 2 and 2a should be thrown together.

DR. STURDEVANT: I think we should keep in mind certain things in the aging of rubber. Certainly many cables have failed without oxidizing the insulation. Heat, sunlight, humidity, and other atmospheric conditions have much to do with the aging of cable.

MR. GRAHAM: Will someone please clarify this for me? I don't believe anyone can tell the difference between failures with these two causes in looking at them. On that basis, and if that's right, why not lump them?

MR. ZINK: Experts cannot differentiate between the two. I think they should be lumped.

MR. ROSCH: The people who gave these answers did differentiate, did they not?

MR. GRAHAM: Can you, Sam?

MR. ROSCH: Yes, I will flatter myself and say I can.

MR. DAVIS: It is pretty hard to separate failures due to heat from those due to natural oxidation. I have been looking at them for 38 years and I can't tell the difference. I think that for the purpose of this questionnaire we should lump 2 and 2a.

MR. MORTENSON: As a means of bringing this matter to a head I now ask the members of this joint committee who are in favor of combining 2 and 2a to make it manifest by raising their right hands.

(All hands were raised.)

MR. MORTENSON: With this show of hands I declare the idea of combining 2 and 2a unanimously carried. It is a vote and so ordered.

MR. GRAHAM: Another word. Item 4 reads, Presence of moisture in cable and Item 11, Deterioration of cable due to exposure to water. There may be a difference but I don't understand what it is.

MR. MORTENSON: Well, Mr. Graham, it is possible, I think, for moisture to enter the inside of a cable without having it exposed to or laying in water on the outside. I recall a case in point. This occurred several years ago on a street car system that was being served by and from a mill that I was then employed by. We were transmitting a low voltage d.c. and had run 750,000 C.M. insulated cable out from the generator switchboard a great distance along the outside of the building and other structures in rigid conduit and tapped it onto a bare copper aerial line of the same cross section. Believe it or not, the copper in that insulated line acted as a wick and within the space of several months we had water running out of that cable back of the switchboard after it had traveled horizontally a few thousand feed and vertically 20 feet or so up the outside of the building to the point of the generator room entrance above the switchboard and we had a blowup. We cured the trouble by stripping the insulation off of the weather loops between the condulet and the bare copper line. So, you see, failure due to presence of moisture in a cable can be different than deterioration of a cable due to its exposure to water.

MR. GRAHAM: If that is what is meant, I see. I agree if everybody understood it in that way they could be classified as separate predominant causes of failure; but, I don't believe they do. There aren't many who can or do differentiate, is my opinion.

MR. MORTENSON: I think, Mr. Graham, if it is the consensus that we should lump them, then that is what we should do.

MR. GRAHAM: It says in the analysis here that many more failures occur due to moisture in cable than due to water. Who knows whether the moisture seeped in because the cable was exposed to water or whether it got in in some fashion such as you described. I don't believe it is possible to tell from the answers as they were given.

MR. MORTENSON: I agree with you 100%. Gentlemen, may we have an expression here? We have lumped 2 and 2a. Shall we do the same thing with 4 and 11? Those in favor please make it manifest by raising their right hand. (4 hands were shown.) Contrary minded, the same hand. (6 hands were shown.)

Gentlemen, there were 4 yeas and 6 nays. So, the nays have it.

MR. ROSCH: For the time being let them remain separate.

MR. MORTENSON: 4 and 11 will remain as they are.

MR. SMITH: This No. 11 did not appear on the original sheet; therefore, it must have been some specific incident where some engineer or engineers had this condition.

MR. MORTENSON: That's right, No. 4 did appear on the original sheet, but No. 11 was added. Smitty's remark is well taken. There must have been good reason. Those who received the questionnaire were men high in their field of endeavor. And that they were well able to differentiate must be taken for granted. So, when they wrote that they had had failures due to deterioration of cable exposed to water they must have had good reason and should be believed.

MR. ROSCH: I think so, both you and they are right. You really have two distinct causes of failure here.

MR. ZINK: The type of insulation makes a difference. Water in rubber cable will run for years. But, in some other cable it might not do so well.

MR. ROSCH: That doesn't alter the fact that there are two distinct classifications.

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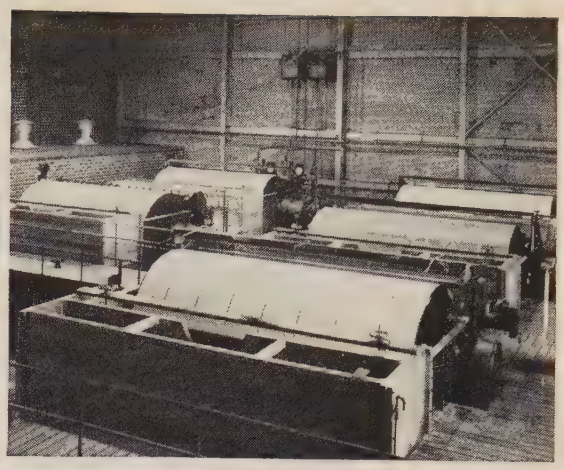

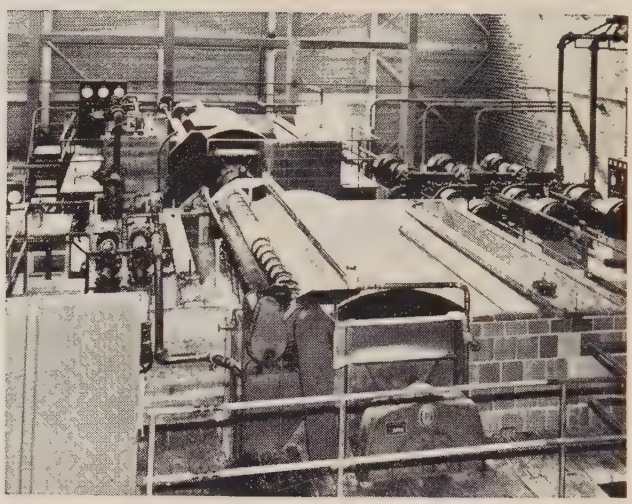

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Mr. Zink: Perhaps not.

Mr. Graham: Look at No. 4. You will find that all mills report a high percentage of failures due to presence of moisture in cable. The word water doesn't even enter the picture in so many, many cases.

Mr. Rosch: Yes, I know, but I would like to study this over just as it is.

Mr. Mortenson: Well, gentlemen, the vote decided the question and we will allow those two (4 and 11) to remain as they are, for the present at least. Any other questions with respect to this key sheet?

Mr. Graham: Along the same lines, I would like to call to your attention No. 1b, Not careful in making up cable stress-cones, potheads, etc., overload; and No. 14, Improper cable termination. Is there any difference in those two?

Mr. Smith: Same thing.

Mr. Mortenson: I quite agree. Let's have a show of hands on this. As many as are in favor of lumping 1b and 14 will please make it manifest by raising their right hands. (All hands shown.) Unanimously carried. 1b and 14 are to be considered as one.

Mr. Davis: One thing that is very decidedly missing on both the questionnaire and the answers is the operating records on a.c. and d.c. I think we should have this. It is very, very important.

Mr. Zink: When d.c. is considered this water question becomes doubly important.

Mr. Davis: How many failures on a.c. and how many failures on d.c. is very important.

Mr. Mortenson: Well, I don't know just what to say. To get that answer now would be most difficult. Too bad we overlooked it in our questionnaire. I only hope that the raising of that question does not eventually result in another questionnaire going forth.

Mr. Rosch: Oh, no. We can get by with the information we have; but, we may have to make some arbitrary recommendations, that we know to be right, when considering d.c.

Mr. Davis: I too hope no other questionnaire has to go out and I don't think one will. But, we might, as Mr. Rosch says, be obliged to draw upon previous records and experiences and knowledge when writing specifications to cover d.c.

Mr. Rosch: It was with that thought in mind that I didn't want those two (4 and 11) combined. This whole question was a great effect upon the recommendations IPCEA will make to TAPPI. The study of the causes for failure is interesting. I suppose it runs back a long time and shows up natural rubber and other materials that are no longer in general use and are no longer made.

Mr. Mortenson: That's right, I think.

Mr. Rosch: When we make our recommendations we will condense it all perhaps to five or six types. This is a guide that should help us immeasurably.

Mr. Mortenson: I believe when we have compiled the information for the various rooms and covered each and every branch of the industry, as we intend to do, we will have a picture that will be very clear and 100% true as to what type of insulation is best to use in every room of every branch of the industry. Then TAPPI can intelligently ask IPCEA for specifications to cover, and IPCEA can in turn intelligently say, "here they are."

I do not think that what we have been able to present thus far gives you (IPCEA) a clear enough picture so that you can answer intelligently now; nor do we ourselves (TAPPI) have a clear enough picture to intelligently put the questions. However, it will be but a matter of time before we can ask you for specifications intelligently and you can give them to us with absolute certainty that each specification will assure the purchaser the very best that the market affords in each and every case.

Mr. Rosch: Acids are mentioned in this key sheet. Now when you speak of acids, are they the same for every branch of the pulp and paper industry? Acids are different, you know. What will stand up in the presence of some won't in the presence of others.

Mr. Mortenson: I am going to refer that question to Larry Clapp, our Technical Director. The question is, when you say acid, Larry, is it the same in all branches of the industry? Larry, take it away. You're on the hot seat.

Mr. Clapp: The only branch of the pulp industry using acid for cooking is the sulphite branch: sulphurous acid. The sulphate branch uses an alkaline cooking liquor.

Mr. Rosch: Let's come back to alkaline. Does everybody use caustic?

Mr. Clapp: No, only the sulphate people. What I am saying is that the sulphite people employ sulphurous acid while the sulphate crowd and others use caustic together with other alkaline compounds.

Mr. Rosch: What I am trying to bring out is that certain types of material good on different types of acid might not do at all against alkalii.

Mr. Mortenson: Does what Mr. Clapp has just said do anything at all to answer the question in your mind?

Mr. Rosch: Yes, it does. It has narrowed it down considerably.

Mr. Mortenson: Caustic base in the *sulphate industry* and sulphurous acid in the *sulphite*. Different in *rag* and *waste paper* and *groundwood*. We will, I hope, have time to go into the various chemicals encountered before the day ends, so you will have it for use in your study.

Dr. Sturdevant: Along the line of cable failures; will your data permit you to associate cable failures with the type of cable? AVC might fail for a very different reason than rubber, for instance, and we should know this.

Mr. Mortenson: I will have to look into the matter before I can answer. Do you remember, Smitty?

Mr. Smith: No, I don't believe so.

Dr. Sturdevant: Has any distinction been made between varnished cambric and AVC with respect to failures?

Mr. Smith: No. We would have to circulate a supplemental questionnaire to bring that out.

Mr. Graham: The tables we have made up are revealing yet quite confusing, I think. For instance, in the first table 2 and 2a are by far the predominant causes of failure, while in the second table No. 1 stands out as the predominant location of failure. How could you tie those two together?

Mr. Mortenson: The two just can't be reconciled but I don't think it means too much. Many failures occur in tapping at the joints and terminals, we know.

Mr. Hogan: Heat due to poor connections could bring about a lot of failures in the terminations and other joints and splices.

Mr. Cooke: Might it be that they are catching the kinds of common causes of cable failures before failure actually occurs. Failure due to age and oxidation and many other things might be picked up by periodic testing.

Mr. Davis: I think in a thing of this kind it is just impossible to stack one summary against the other. The first merely lists the types of failure, while the second lists the location of the failures; one without much or any regard for the other, making any check between the two meaningless.

Mr. Graham: Was it so intended?

Mr. Davis: I wouldn't worry too much about that. Whether they tie together or not doesn't much matter. If the number of cable failures tabulated on your first sheet doesn't check with the number of locations at which failures occurred as tabulated on your second sheet, don't be too technical. Add two and two together and get seven. Not necessary to be too exacting.

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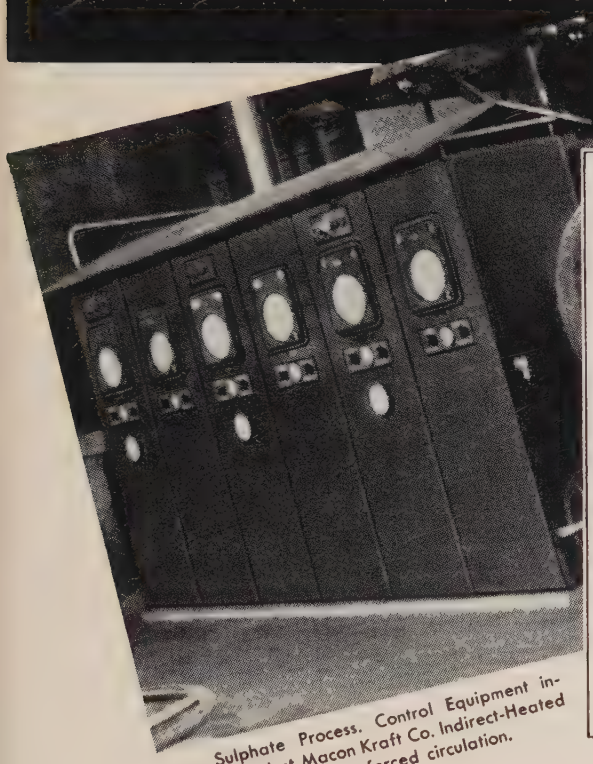

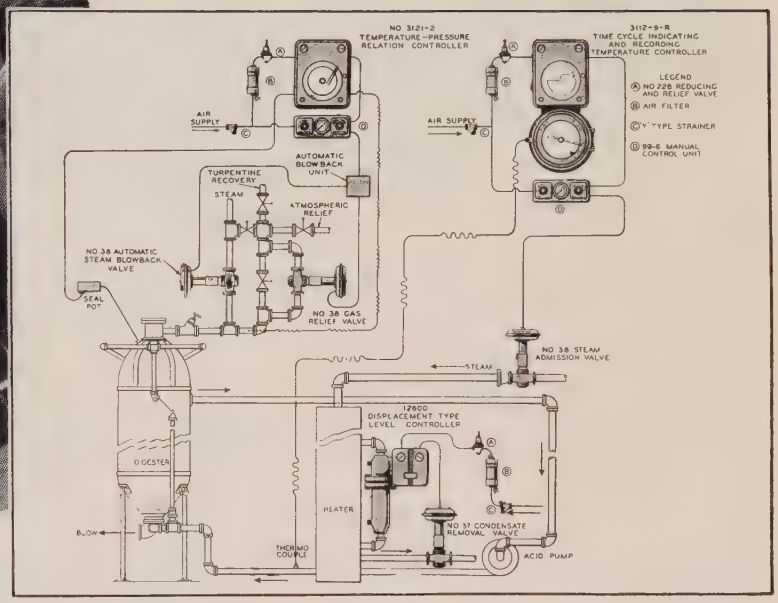

Sulphate Process. Control Equipment installed at Macon Kraft Co. Indirect-Heated Digesters having forced circulation.

Masoneilan Digester Controls eliminate the guesswork from the cooking process. They produce better, more uniform pulp at lower manufacturing cost. Once a cycle is determined, these automatic controls will repeat any selected program time after time.

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Mr. Zink: That's right. We do not have to be too exacting. We have to look at the over-all picture. 2 and 2a, Deterioration of cable insulation due to age and Deterioration of cable insulation due to oxidation, I am under the impression that a lot is due to heat at take-offs and such, just as Mr. Hogan says. Any type of cable aging problem in the field is pretty tough if not impossible to analyze.

Mr. Davis: When you speak of effect due to oxidation, more of your trouble is overload than anything else. True aging is a different story. But, it is hard to differentiate. I think lumping of 2 and 2a was the proper thing to do.

Mr. Mortenson: Gentlemen, the failures as reported have, without doubt, occurred in all types of insulation ever used and the different types have, no doubt, failed in just about every spot reported. But, we can't tell what did what where and I don't think we are very much concerned with it anyway.

Mr. Davis: We had better take the information away with us and study it. We know we are up against acids and alkalines and perhaps other chemicals. Also a lot depends on temperature. Because neoprene is now used extensively as a cover does not mean that it is good for all conditions and circumstances. I think this afternoon, if we can get more information on what chemicals are in the room we are dealing with we can get together later and agree on specifications and recommendations.

Mr. Mortenson: Mr. Davis, the point you have just made is well taken. Now, for the purpose of the record I think it wise and smart to have someone read into the record, from the notes you made at the morning session, what the predominant causes of failure are and where they have been.

Mr. Smith: What do you want me to read?

Mr. Mortenson: Where the stuff failed most often, what caused the most failures, and where the most failures were. We should have that information in three places: first, second, and third.

Mr. Smith: The table below is on common causes of failure:

Mr. Mortenson: How does it look across the board, gentlemen? Any definite pattern?

Mr. Smith: Nos. 2 and 2a across the board.

Mr. Rosch: As well as No. 4.

Mr. Cooke: And No. 1.

Mr. Mortenson: Thanks, Smitty. Now we will take a look at chemicals.

Mr. Graham: Thought we were going to do the same with this second sheet.

Mr. Mortenson: Right. Glad you reminded me. Proceed, Smitty, please.

Mr. Smith: Predominant location of failure, second sheet.

	Sulphite Mill	*Sulphate Mill*
First	No. 1	No. 3
Second	No. 2	No. 2
Third	No. 3	No. 1

Mr. Mortenson: Just wish to inject a remark. Seems peculiar that the location would reverse exactly between the two branches of the industry, sulphite and sulphate.

Mr. Rosch: Figures not too far apart either.

(Mr. Smith continues reading from yellow sheets.)

	Groundwood	*Rag*
First	No. 2	No. 3
Second	No. 1	Nos. 1 and 2
Third	Nos. 5 and 6	Nos. 5 and 6

	Waste Paper	*Others*
First	Nos. 1 and 2	No. 1
Second	Nos. 3 and 11	Nos. 2 and 3
Third	No. 0	No. 5

Mr. Mortenson: I want to take just a minute out to let Justin Weddell, the St. Regis Paper Co.'s Public Relations Director, meet you all personally. He is a chap who knows more about public relations than any other ten men living. These people with me are splendid people also, Justin, and you will learn their connections as well as their names as you meet them.

(Introductions made and acknowledged. Mr. Weddell leaves after having sat in on the afternoon session.)

Mr. Cooke: Common causes of failure, in all cases, you have given us, the total number of answers. But, you have not for the location of failures.

Mr. Graham: You don't have to on that page.

Mr. Cooke: Numbers do not total up.

Mr. Graham: This is a percentage of failures.

Mr. Mortenson: No, they don't, I agree. Here they are. *Sulphite* total reported locations of failure was 25, *sulphate* 33, *groundwood* 7, *rags* 9, *waste paper* 6, *others* 50. So you see there were a number of people who gave causes of failure but did not tell us where they occurred.

Mr. Mortenson: So much for that. I will now pass around the sheets that Larry Clapp got out for the first meeting and they will give you the required information on chemicals in the sulphate industry.

(Mr. Mortenson passes sheets entitled "Chemicals and Conditions Encountered in a Typical Southern Sulphate Pulp and Paper Mill.")

Mr. Zink: This will be a big help.

Mr. Mortenson: Gentlemen, this questionnaire I am holding in my hand is from the ——— company. They tell us on the back sheet what chemicals are encountered in their plants. This will be a good check against our plant and our Technical Director. Going to put you on the hot spot again, Larry. Please, take over and explain all this to the conference.

Mr. Clapp: Okay.

(Mr. Clapp writes this particular company's chart on blackboard thusly:)

Composition of Various Liquors and Solutions

Mill Alum—1.25 lb. $Al_2(SO_4)_3$, $14H_2O$ per gallon
Rosin Size—0.0535 lb. 70% size per gallon
Milk of Lime—1/4–lb. CaO per gallon
Bleach Liquor—30 g. available CL_2 per liter
Black Liquor—0–62% solids activity—21.1%

Sulphite Mill

First	Nos. 2 and 2a
Second	No. 4
Third	Nos. 1 and 6

Sulphate Mill

First	No. 1
Second	No. 4
Third	Nos. 2 and 5

Groundwood

First	Nos. 1 and 2
Second	Nos. 4
Third	Nos. 5, 9, 14, and 15

Waste Paper

First	Nos. 2 and 2a
Second	Nos. 1 and 5
Third	No. 4

Rag

First	Nos. 2 and 2a
Second	No. 4
Third	Nos. 1 and 5

Others

First	Nos. 2 and 2a
Second	No. 4
Third	No. 1

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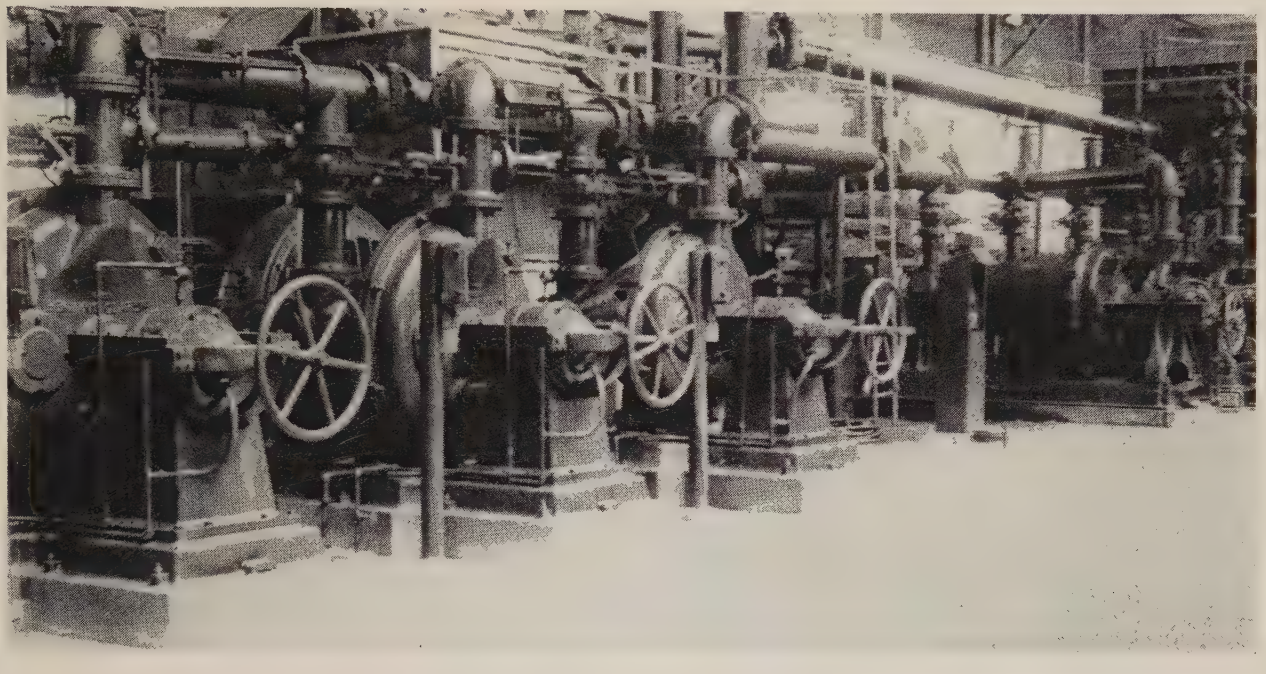

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LANCASTER, OHIO

White Liquor—101 g. NaOH per liter
43.0 g. Na_2S per liter
36.1 g. Na_2SO_3 per liter
5.7 g. Na_2SO_4 per liter
Green Liquor—20.0 g. NaOH per liter
43.0 g. Na_2S per liter
133 g. Na_2CO_3 per liter
3.7 g. Na_2O_4 per liter
Dyestuff Solution—$^1/_4$–4 oz. dye per gallon
Sodium Silicate—37° Bé. at 60°F.
Bleach Plant Effluent pH—2.1
Pulp Mill Effluent pH—9.5
Paper Mill Effluent pH—6.5
Urea-Formaldehyde Resins—1 lb. solids per gallon

(Mr. Clapp explains that this company figures grams per liter. We, here at this mill, figure pounds per gallon.)

Mr. Mortenson: Something more I notice about this questionnaire. I will pass it around and let you look at it. Notice in Service—Motor Leads, Motor Control, Lighting, Prime Feeders, Subfeeders, Generator Leads, and Others, they use Kerite throughout. Prime Feeders and Subfeeders they say "G," which is varnished cambric lead; and "2," which is Steel Conduit Underground. Kerite. Generator Leads they say "I," which is varnished cambric and braid. In turbine room, paper machine, and such they say natural rubber braid and steel conduit exposed.

(Mr. Mortenson passes questionnaire around for perusal.)

Mr. Mortenson: Note too that they say all their failures have been due to age and electrolysis. Occurs everywhere.

Now, will one of you gentlemen please pass the *Sulphite* questionnaires to me. We will look them over for chemicals and turn them over to Larry for elucidation.

(Mr. Clapp reads chemicals encountered from questionnaires.)

Mr. Clapp: Digester Room—calcium $CaHSO_2$; Washer Room—water; Screen Room—water; Decker Room—water; Machine Room—water; Bleach Plant—Chlorine; Sulphur Burner Room—dioxide SO_2; Acid Making Plant—$CaHSO_2$.

Mr. Mortenson: Here's another questionnaire. Tell us what we have here.

Mr. Clapp: Chip Preparation—traces SO_2; Wood Yard—traces SO_2; Wood Room—traces SO_2; Digester Room—humid conditions plus SO_2 gas in the air; Washer Room—none; Screen Room—Humid conditions, diluted cooking liquor plus SO_2 and chlorine gas; Decker Room—same as Screen Room; Stock Preparation Room—humid conditions plus acidic solution due to aluminum sulphate in stock Machine Room—humid atmospheric conditions; Finishing Room-ideal atmospheric conditions; Bleach Plant—bleach liquor, chlorine water solution, chlorine gas, and humid condition; Power Boiler Room—high temperature plus traces of SO_2 gas; Sulphur Burner Room—SO_2 gas; Acid Making Plant—SO_2 gas, sulphite cooking liquor, humid condition; Wet Machine Room—humid condition and traces of bleach liquor, CL_2 and SO_2 gases.

Mr. Mortenson: Here's another, Larry.

Mr. Clapp: Chip Preparation—wood dust; Wood Room—dust and water. The others just about the same but in addition to what the others say, this particular company mentions under Stock Preparation Room—clay and talc dust, water, alum, and size.

In recovery room one mill mentions wet lime. And this one says sunlight.

Mr. Mortenson: That's it for sulphite branch, gentlemen.

Mr. Rosch: Various solutions run about same pattern?

Mr. Mortenson: How about it, Larry?

Mr. Clapp: Yes, I believe so.

Mr. Mortenson: Here are the questionnaires for *Rags*. More chemicals in the rag business than in any other it seems. All right, thanks, Larry.

Mr. Rosch: Mr. Mortenson, while Mr. Clapp is getting the chemical dope from those rag questionnaires, could we take this time to decide the place of the next meeting?

Mr. Mortenson: Certainly.

Mr. Zink: Why not in the Adirondacks?

Mr. Davis: Do you come to New York occasionally, Mr. Mortenson?

Mr. Mortenson: Yes, I do.

Mr. Davis: Most of the crowd here come closer to that section of the country than any other. So, for convenience to them we should meet in or near New York, I think. Two or three months after the cable fellows have had this material and have studied it we can notify you that we are ready for another meeting. You can set a date, in the vicinity of New York, sometime when you are up there. Does that sound too unreasonable?

Mr. Mortenson: No, I don't think so. Is it the consensus that we meet next in New York?

Mr. Rosch: Providing you bring Miss Miller.

Mr. Mortenson: Perhaps that can be arranged. The consensus is overwhelming that we meet next in or near New York City, and it is so ordered. Now as to who shall arrange that meeting. Is there someone we could get in touch with? Who can take on the arrangements?

Mr. Davis: A good place to have it would be at the Engineers' Club or the AIEE. I'll be glad to take care of it for you.

Mr. Mortenson: Okay. Mr. Davis will arrange for the next meeting. It will be two or three months hence after IPCEA has had a chance to compile this information to a greater extent, study it, and come up with some answers.

Mr. Davis: The Insulated Power Cable Engineers' Association will have to get together. They will need the minutes of this meeting, which I imagine will not be out for two or three weeks hence.

Mr. Foster: A TAPPI meeting is scheduled for the middle of October.

Mr. Mortenson: At Savannah we will be obliged to make just a preliminary or progress report. But, with the wealth of information at hand it might be quite voluminous at that.

Mr. Graham: Do we have time for our next meeting before that?

Mr. Mortenson: I doubt it very much. Okay, Larry, let's go on *Rags*.

Mr. Clapp: Only two of these replies itemize the various locations of these chemicals. Bleach Plant—chlorine; Power Boiler Room—lime, soda ash, phosphate; Finishing Room—alum; Rag Cooking—lime, soda ash, caustic; Rag Washing—chlorine, sulphuric acid and Rag Bleaching—same items.

Other replies listed alum, sodium hydroxide, silicate of soda, sodium hypochlorite, sulphuric acid, chlorine, starch casein, clay, and formaldehyde. Those are probably employed in the Coating Room, although they are not so listed.

Mr. Mortenson: *Waste Paper*, no chemicals.

Mr. Clapp: Unless doing some deinking.

Mr. Mortenson: Must be just water in *Waste Paper*. Now let's go to *Others*. This covers everything—every room and department in every branch of the industry.

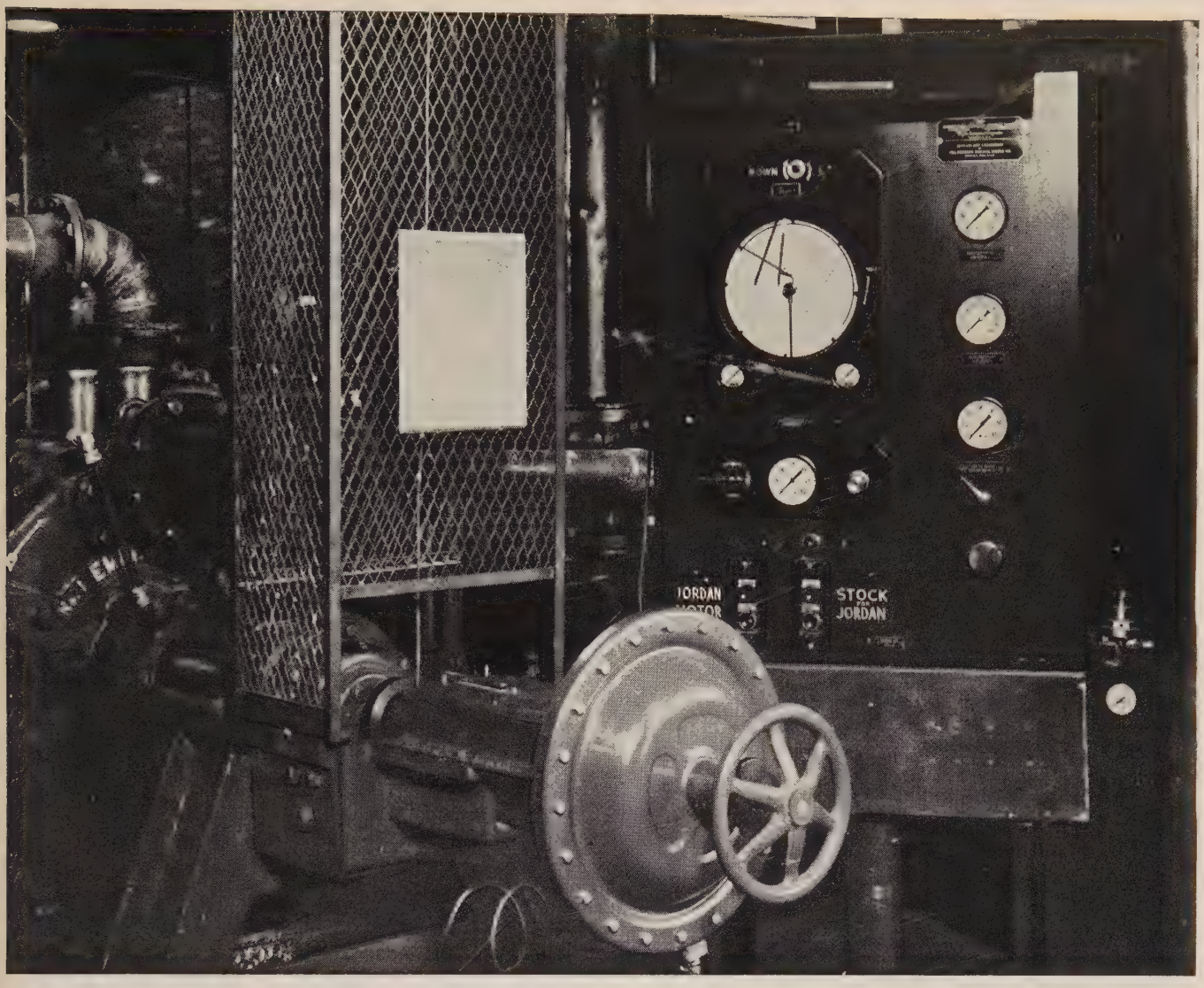
(Mr. Clapp reads through the stack of papers to see if there is anything different, not mentioned before.)

Mr. Clapp: There is nothing different in any of these.

Mr. Mortenson: That's it for chemicals. Gentlemen, the only thing that we haven't gone into at all, which is something that we were not charged with looking into by the Association but something which we did look into as, well, just an adjunct to what we were doing, was how the wire and cable were installed in the mills and what types of installation were preferred. We haven't taken any of the information from the questionnaires concerning that yet, although it is all there. It is something that will come to you later. We will perhaps append it to the minutes.

Mr. Rosch: When you say how cable was installed, just what do you mean?

Mr. Mortenson: The nature of how it was installed: whether in conduit, raceways, open, on cleats, what-have-



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you. For instance, here is a fellow who puts "D" in 7, that is conduit exposed (sherduct). He does that throughout, steel conduit exposed. I have looked at two or three of these reports with an eye to how they like to install their cable. Steel conduit exposed seems to predominate.

Mr. Rosch: Only reason I can see for conduit would be to protect the cable from mechanical injury. If the cable is exposed the chances are better to ward off chemicals. Racks, trays, anything like that, where the wire or cable can be open, is better than conduit.

Mr. Graham: I agree with you.

Mr. Rosch: Corrosion takes a heavy toll. Conduit or any other closed raceway for cables can be very detrimental to the cables by confining injurious chemicals and fumes and keeping them from escaping. Also when cables are enclosed in anything, larger sizes, greater cross section must be employed to compensate for the entrapped heat.

In many buildings in New York that have been renovated or dismantled cables were found in deplorable condition, when they were pulled out of conduits, due to having been locked up in musty, dirty, murky, often chemically laden atmospheres. I would like to see cables exposed.

Mr. Mortenson: Here are people (Piedmont) who collaborate with you, Mr. Rosch. They say conduit exposed for motor leads, motor control, and lighting. But for prime feeders and subfeeders they say something different. They say, open. Right in line with what you have just said.

Mr. Graham: Is the open work you were talking about different from an open tray?

Mr. Mortenson: No, that's one style or type of open work. These people say conduit exposed for motor leads; say different for motor controls, IAC.

Mr. Rosch: Very good idea.

Mr. Smith: I think it a damn good idea.

Mr. Rosch: Mechanical protection.

Mr. Mortenson: Conduit underground for generator leads.

Mr. Cooke: All right. This information that has come out of this questionnaire is a very broad and clear picture of what is going on. Think really our job is to look at this information with an eye to the results of habit over a great number of years of experience by those who answered. Habit may have influenced them in a great many cases. We should keep that in mind. Our recommendations to the industry should not be confined to reflect only our answers to the questions raised by the trends shown in the replies to our questionnaire. The field is big and broad and we should recommend that which our combined knowledge tells us is best for the pulp and paper industry.

Mr. Rosch: You are echoing what I already said to Mr. Mortenson right after lunch.

Mr. Cooke: Speaking of methods of installing wiring, rigid conduit exposed may be all right in certain places but many people are now getting away from it. The chemical industry, for instance, is going to exposed wiring up in racks or trays, getting away from conduit. In making our recommendations we should consider the economic aspect as well as all others. If we don't think a thing is right economically, I don't think we should hesitate to recognize it and recommend against it. I am not a cable expert myself; but I think we know that there are a number of types of cables that would fit into this category. We should make the number of types recommended for each service as small as possible. From my standpoint, either one or two instead of five or six.

The pulp and paper industry makes pulp and paper. They are not cable experts. We should do our best to help them out of a confusing situation. We might come down to a few ways of doing a thing that is now done in many ways. Confine and concentrate, in other words, make things easier all around.

Mr. Mortenson: What you have said, Shelby, is all well taken.

Mr. Davis: Another thing, d.c. operation. I don't think it necessary to send out another questionnaire. We have more trouble with d.c. operation but I think we can recognize that and go ahead and make the proper recommendations.

Mr. Mortenson: Ray Foster has been in the paper industry for many years. Let's see how he feels about that.

Mr. Foster: Certainly true that a lot of our troubles have been on d.c. Don't see the necessity, however, to put another questionnaire out. But d.c. certainly has to be considered.

Mr. Davis: The questionnaire would not help us too much. We can make a study of our own and come up with recommendations to cover d.c. without too much trouble, I think.

Mr. Foster: From my experience, the troubles have been greater on d.c. cables, I think.

Mr. Davis: Yes, that would be true under certain conditions.

Mr. Graham: Rather peculiar that someone did not mention d.c. in answering the questionnaire.

Mr. Mortenson: Would like to hear from Mr. Smith for just a minute. He has been in the industry, designing engineer capacity, for quite some time. What is your opinion?

Mr. Smith: I have experienced many d.c. failures and there is need for specific recommendations for d.c. Sorry we overlooked it in our questionnaire. As the gentlemen say, wet location failures predominate on d.c. However, we have been using the same type of cable throughout on our d-c drives as on a.c. I think Mr. Davis remarked that we should come out with a special recommendation for d.c.

Mr. Mortenson: Ray, had you completed all you wanted to say?

Mr. Foster: My experience with d.c. has extended over a number of years. We have used primarily a 30% rubber compound in conduit in wet locations and we haven't had too much trouble. The newer compounds have not been on the market long enough for us to know what they will do.

Mr. Mortenson: Is that everything? Think Mr. Zink started to say something.

Mr. Zink: Was just going to say that I agree with Mr. Davis. We should write specifications to cover d.c.

Mr. Mortenson: Well, gentlemen, I think that we have gotten into the pot just about everything that we have to offer today. And it is a case of letting the pot simmer, and we hope, come up with a cook that will be worth while.

If there is nothing further to be brought before us we can start cleaning up and start thinking of adjourning. However, we will remain here just as long as anyone present wishes. If anything further of consequence can be injected into the minutes, believe me, we will stay.

Mr. Foster: Think maybe a lot of the presently installed d.c. is 225 volts, 600 volts insulation. Nowadays we are going to 600 volts d.c. which, of course, requires much better insulation.

Mr. Mortenson: Thanks, Ray. I would like to say one more time, on behalf of TAPPI and the TAPPI Electrical Engineers Committee, that we feel greatly indebted to the Insulated Power Cable Engineers' Association for collaborating with us as they are. You have TAPPI's very sincere thanks. I hope that when you get to your meeting to consider what you have taken from here that you will convey TAPPI's sincerest thanks to your Association.

Mr. Rosch: We certainly will. And may I say that I think it would be nice if you would send a note of thanks to the Secretary of IPCEA. I know the rest of the fellows would appreciate it.

Mr. Mortenson: You bet I will. And now, gentlemen, we stand adjourned to meet two or three months hence.

The meeting adjourned at 4:50 p.m.

A. O. Mortenson, *Chairman*
TAPPI Cable Subcommittee
Electrical Engineering Committee

LOCAL SECTION ACTIVITIES

Reports of Meetings, Personnel, and Events

Lake Erie

Friday, July 20, was a busy day for the Lake Erie Section of TAPPI. The day started with visits to the Ohio Match Co. in Wadsworth and the Jaite Co. in near-by Jaite, Ohio.

About 30 of the 75 attending the outing were treated to a very complete tour of the Match Co. operations from forming the matches themselves to the printing of the cover stock. The visitors saw many interesting operations, including the manufacture of regular wooden matches as well as the more commonly used paper book matches. Rotogravure printing, continuous web typographic, and flatbed letter press printing were observed. Considerable interest was centered in the high-speed automatic packaging lines.

A smaller group visited the Jaite Co., where the visitors saw the two fourdrinier paper machines in operation making stock for the multiwall kraft bag plant.

A cocktail hour and luncheon at the Barberton-Brookside Country Club was followed by golf, horseshoes, softball, and the usual informal indoor sports. Prizes were awarded for the various events.

Among the distinguished visitors was Kenneth P. Geohegan, Vice-President of the Howard Paper Mills, Dayton, Ohio, and President of TAPPI, who spoke at the luncheon. Mr. Geohegan stated that he had been following the progress of the Lake Erie Section and had been pleased with the Section's progress. He held high hopes for the future of the Section. Mr. Geohegan also sat in on the meeting of the Executive Committee called by William Hasselo, the new Section Chairman.

The principal subject discussed was the program for the 1951–52 season. The dates of these meetings and the subject matter are listed below:

Oct. 19	Why Converters Aren't Satisfied.
Nov. 16	Does a Training Program Pay.
Dec. 21	Christmas Party.
Jan. 18	Tomorrow's Industrial Protective Packaging. A Symposium—5 Speakers.
Feb. 15	Cashing in on Suggestion Systems.
Mar. 21	Graphic Arts.
Apr. 18	Practical Process Controls for Better Quality.
May 16	Folding Carton Meeting.
July 18	Summer Meeting.

It was decided that there would be a minimum of two speakers per meeting, and that the meeting would be at the Hickory Grill in Cleveland, Ohio.

R. L. Lewis, *Publicity Chairman*
Lake Erie Section

John Preston, Federal Adhesives Co.; W. A. Foll, National Adhesives Co.; and A. J. Krusick, Paisley Products Co.

Maine-New Hampshire

The Maine-New Hampshire Section will hold its Fall meeting at the University of Maine on Oct. 5–6, 1951. Room reservations should be made at the Bangor House, Bangor, Me. On Saturday, Oct. 6, the University of Maine football team will play the University of Vermont. George A. Day of the Brown Co., Berlin, N. H., is Chairman of the Maine-New Hampshire Section.

Lake States

The first meeting of the Lake States Section will be held at the Conway Hotel, Appleton, Wis., on Sept. 20, 1951. Dr. B. Steinberg of the Swedish Forest Products Research Institute will discuss "Paper Properties." Dr. Steinberg will be one of a number who will be in Appleton during the week of Sept. 16 to participate in the TAPPI Fundamental Research Conference. It is expected that many of these visitors will be present at the Lake States Section meeting.

Empire State (Metropolitan District)

The Metropolitan District of the Empire State Section will meet at Fraunces Tavern at 6:30 p.m., Oct. 9, 1951.

H. Vandenberg and C. Gehring, both with A. E. Staley Mfg. Co.; J. Noll, Monroe Falls Paper Co.; L. Theil, F. C. Huyck & Sons, Inc.; and L. J. Whims, Ohio Boxboard Co.

COATINGS

Pyroxylin supplies coatings of great diversity of type and end use to the paper and converting industries. An incomplete list below gives a picture of the variety of uses,—it also suggests related fields in which Pyroxylin's products may be able to solve your problem.

Folding Cartons	Glassine
Soap Wrappers	Playing Cards
Laminated Papers	Frozen Food Canisters
Masking Tapes	Heat Seals & Bands
Maps	Decalcomanias
Parchment	Picture Post Cards
Booklet Covers	Separation Sheets
Electrical Insulation	Box Liner
Bakery Caddies	Mimeo Stencils
Imitation Leather	Crown Cap Spots
Photographic Papers	Greaseproof Papers
Military Barriers	Labels

What does it cost to apply such coatings? Here is a sample calculation derived from unit price, non-volatile, weight per unit, and film requirement. The method is generally applicable in calculating coating costs and in checking coating machine operation.

Glassine is lacquered in large quantity with a moisture-proof heat sealing lacquer. The raw weight of this glassine is 25 lbs. per ream (3000 sq. ft.) or 8 lbs. per 1000 sq. ft. To secure satisfactory moisture proofness it has been found by experiment that 4.0 lbs. of film must be applied equally divided between the two sides. The lacquer weighs 6.64 lbs. per gallon and contains 30 per cent non-volatile. It is obtainable at $2.88 per gallon.

Cost lacquer—$2.88 per gallon
Non-Volatile—30%
Weight lacquer—6.64 lbs. per gallon
1 gal. lacquer—6.64 × 30—1.99 lbs. non-volatile per gallon

Hence

1 lb. film deposited—$\frac{\$2.88}{1.99}$ = $1.44 per lb. non-volatile

25.0 lbs. (3000 sq. ft.) glassine at $.24—	$6.00
4.0 lbs. lacquer film at $1.44	5.76
29.0 lbs. lacquered glassine	$11.76

Since the 25 lb. glassine has been changed by the lacquering process to 29 lbs. glassine, the per lb. cost of this glassine now is $.40. To such a figure must be added converting cost and burden.

This is the fourth of a series of advertisements describing our products to TAPPI members.

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There will be a panel discussion on the purchasing of raw materials, operating supplies, etc. Several purchasing agents will participate. Stress will be put on the technical aspects and specifications of the materials purchased.

Ohio

The Program Committee and Officers of the Ohio Section of TAPPI met at Fort Ancient State Park on Sunday afternoon, July 29, to complete plans for the program for the 1951–52 season. Members of the Program Committee present were: John L. Clouse, Chairman, Walter Johnson, Harold Joiner, Lee Buechler, George Gregg, Fred Holt, and Russ Buck. H. A. Smith, Chairman of the Section, C. E. Brandon, Vice-Chairman, and R. D. McCarron, Treasurer, were also present. M. A. Youtz of Battelle Memorial Institute and Col. M. A. Peerenboom were guests for the afternoon. Following the meeting a picnic lunch was enjoyed by the members and their families.

The tentative program outlined by the Committee follows:

Oct.	8	An afternoon and evening meeting held at the Hotel Manchester, Middletown, Ohio, with Dr. Steenberg leading the discussion.
Nov.	8	Evening meeting at the Hartwell Clubhouse of the Cincinnati Gas & Electric Co. with W. C. Bloomquist of General Electric speaking on "Gas Turbine Applications in the Paper Mill."
Dec.	11	Afternoon and evening meeting to be held at the Battelle Memorial Institute, Columbus, Ohio, with a tour through Battelle Institute in the afternoon and a talk on Graphic Arts in the evening.
Jan.	10	Evening meeting at the Hotel Manchester, Middletown, with Paul Cope of Procter and Gamble speaking on some phase of packaging.
Feb.	12	Evening meeting at the Hotel Manchester on the subject of testing. Meeting to be preceded by demonstrations of testing equipment.
Mar.	13	Evening meeting at the Hotel Manchester with Clark Everest of the Marathon Corp. as speaker.
Apr.	8	Afternoon and evening meeting to be held at Chillicothe, Ohio. Observation of a Deculator in action is planned for the afternoon followed by dinner and a speaker.
May	8	Annual meeting, location, and program to be announced later.

The opening meeting of the Ohio Section of TAPPI will be held on Monday, October 8, at the Hotel Manchester, Middletown, Ohio. The speaker for this meeting will be Dr. Borgje Steenberg, Professor of Paper Technology, Royal Institute of Technology, Stockholm, Sweden. He will speak on the subject "The Effect of Some Paper Machine Variables on the Properties of Paper."

Lake Erie Section Executive Committee Meeting: L. K. Burnett, Ohio Boxboard Co.; K. P. Geohegan, President of TAPPI; Howard Paper Mills, Inc.; W. Hasselo, Chairman, Container Corp. of America; L. E. Rolig, Secretary, Ohio Boxboard Co.; W. Schoenberg, Treasurer, Lord & Schoenberg, and A. Cheely, Hankins Container Corp.

Paper and Packaging Specifications

U. S. Government Specifications

Following is information from B. W. Scribner, National Bureau of Standards, Chairman, Technical Committee on Paper and Paper Products, Federal Specifications Board, on Federal specifications of recent issue. These are all revisions:

Paper, Mimeograph, UU-P-388e; Price, 5 Cents

Three additional weights of groundwood paper, in which not less than 60% of groundwood pulp is required, have been added. The basis weights are now, 16, 18, 20, and 24 (17 × 22–500). The requirements for the new weights were based on the recommendations of the Groundwood Paper Manufacturers Association.

Paper, Kraft, Wrapping, UU-P-268c; Price, 5 Cents

No. 3 and imitation kraft wrapping have been deleted, tearing resistance has been substituted for the folding endurance requirements, and the bursting strength requirements have been decreased. The revision was prepared with the assistance of the Kraft Paper Association.

Tape, Paper, Gummed (Sealing and Securing); UU-T-111b; Price, 5 Cents

The bursting strength requirements have been deleted, and tearing resistance and tensile breaking strength are now specified for all of the different weights of paper. An additional test for adhesiveness, based on TAPPI method T 463 m which employs the Harnden-McLaurin sealing tape tester, is now specified. The Gummed Industries Association assisted in the revision.

Boxes, Fiber, Solid (for Domestic Shipment), LLL-B-636c; Price, 10 Cents

A larger box having combined inside dimensions of 100 inches, and a requirement for nonbreakage of closures when tested by a drop test, have been added.

Boxes, Fiber, Corrugated (for Domestic Shipment), LLL-B-631c; Price, 10 Cents

A table containing "Special requirements for corrugated fiberboard" having higher bursting strengths specified, has been added.

Boxes, Wood, Wirebound (for Domestic Shipment), NN-B-631c; Price, 15 Cents

The maximum weight of contents has been reduced to 500 pounds, and the thickness of boards is now specified for easy, average, and difficult loads.

(A revision of the Federal Specifications Index, revised to Jan. 1, 1951, has been issued under the new title, "Federal Specifications and General Services Administration Specifications Index." This and Federal specifications may be obtained on application accompanied by money order, coupon, or cash to the Superintendent of Documents, Government Printing Office, Washington 25, D. C. The price of the Index is 35 cents.)

Standardization of Testing Methods

D. I. Sutherland, at the Fifth General Conference of the Australian Pulp and Paper Industry Technical Association, held at Burrie, Tasmania, on March 17–22, 1951, presented a brief report of the experiences of the Australian Paper Manufacturers Ltd. Testing Committee relative to the Standardization of Pulp and Paper Testing Methods. His remarks follow:

The pulp and paper industry uses a wide variety of testing methods on raw materials, on finished products, and during production.

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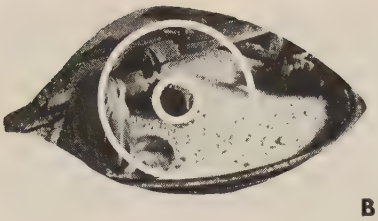

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structions for those tests in which it was interested independently of the other laboratories.

In most cases the laboratory took the testing instruction for TAPPI or the British Paper Makers' Association. As these instructions had been prepared after critical examination of the method, they were accepted without question. Unfortunately it was found that the TAPPI instructions gave insufficient detail, with the result that different operators were unintentionally making different interpretations of the instructions, and as a result were using different procedures. This was first evidenced with the water resistance test, where differences were found to be due to this reason. A further matter which cast a shadow on the TAPPI methods was the tearing resistance method, which gave an instrument specification which was not met by any of the instruments in general use in Australia, and, as far as is known, elsewhere.

To eliminate these faults a Testing Committee was set up under the Chairmanship of the Chief Works Chemist and consisted of the Chief Chemist at each mill, the Chief Chemist of Central Laboratory, and the Research Laboratory Superintendent.

One of the first tasks undertaken was to set up an index of testing methods to include those in use at that time, and to allow for future methods which may be desired. The Index was classified into five main sections: Preparations, Equipment, Mill Operating, Testing, and Miscellaneous.

Listed in this Index were over 200 methods, and the Committee then tackled the task of preparing drafts of these methods. As a first step regulations were prepared covering the procedure to be used in writing standard methods, and the methods were divided into groups which were allocated one to each mill.

Since that time the mills have been working through the lists and, as a result, 40 standard methods have been prepared. Attention has in general been concentrated on methods where differences have been found, or where there is no recognized method already available. It should be mentioned that for most of the remaining 160 methods the TAPPI methods have been used by all operators without encountering the abovementioned faults.

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P151-51. Young engineer, preferably mechanical or electrical, for position as assistant to paper mill engineer. Location in New York State.

P152-51. Graduate Chemical Engineer for research work on bagasse. First year's work to be carried on at Northern Regional Research Laboratory at Peoria, Ill. If project develops as anticipated man will be eligible for key position in the commercial enterprise projected in Hawaii.

P153-51. The Quebec North Shore Paper Co. requires a man to head up a new research group at Baie Comeau. The work is directed to the fundamentals of papermaking and paper machine design. Applicants should have an Honors' degree or a Doctorate in either Mechanical Engineering, Chemical Engineering, or Engineering Physics, and must have some knowledge and experience of organizing research. Some knowledge

of paper manufacture is desirable. When replying, give full details of education, experience, marital status, and include photograph. Address replies to Personnel Manager, Baie Comeau Mill, Baie Comeau, Que., and mark the envelope confidential.

P154-51. Pulp Stone Sales Engineer for large manufacturer of abrasive products. A graduate Mechanical or Chemical Engineer preferred, age group 25 to 38 years. Must have knowledge and operating experience in groundwood mill; be able to judge pulp and interpret physical tests of groundwood. Must know pulp stone sharpening methods and equipment. Starting salary $400 per month and up, depending on qualifications. Will participate in Sales Bonus plan.

P155-51. Paper Chemist. Position open in product development, market research, and technical sales work with surface-active chemical manufacturer in New York area. Requires paper school graduate with organic chemistry minor having imagination and initiative. Several years' experience in paper industry desirable. Please state qualifications, experience, and salary requirements.

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P157-51. Supervisor for a testing laboratory specializing in quality control and evaluation services. Located in the New York Area.

P158-51. Papermaker needed for plant in Formosa. $1^1/_2$-year contract.

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E139-51. Technical Director or Assistant Superintendent. Graduate Institute of Paper Chemistry. Fourteen years' experience in sulphite specialty papers and pulp. Chief Chemist in mill making rag bonds and related specialties. Experienced in sales work.

E140-51. Mill Manager, Assistant or Production Manager, or Engineer available. Fifteen years' experience in technical and practical aspects of papermaking. Excellent administrative ability.

E141-51. Chemical Engineer. 29, married, two children. Four years' operation and supervisory experience in control, groundwood, sulphite, and fourdrinier machines. Desires position in technical department of pulp and paper mill or in production or technical department of an affiliated industry. East coast location desired.

E142-51. Patent Attorney. 43, married and draft-exempt, Ph.D. Columbia University, 1937. Registered before U. S. Patent Office. Over five years' patent experience plus five years' industrial experience. Desires part-time work. Field of special knowledge includes pulp and paper, petroleum, plastics, and synthetic paints.

E143-51. Technical Superintendent and Assistant Manager with B.S. degree desires position. Experienced in control and manufacture of fine industrial papers.

E144-51. Development Engineer—8 years' diversified experience. Fields include pulp and paper, process equipment, plastics, pharmaceuticals. Functions include liaison, laboratory and pilot plant development, production. Draft exempt. Location immaterial.

Note: In responding to employment service inquiries time will be saved if responses are addressed to the Technical Association of the Pulp and Paper Industry, 122 E. 42nd St., New York 17, N. Y. Individuals are urged to include a carbon copy of their responses so that one can be kept on file for reference.

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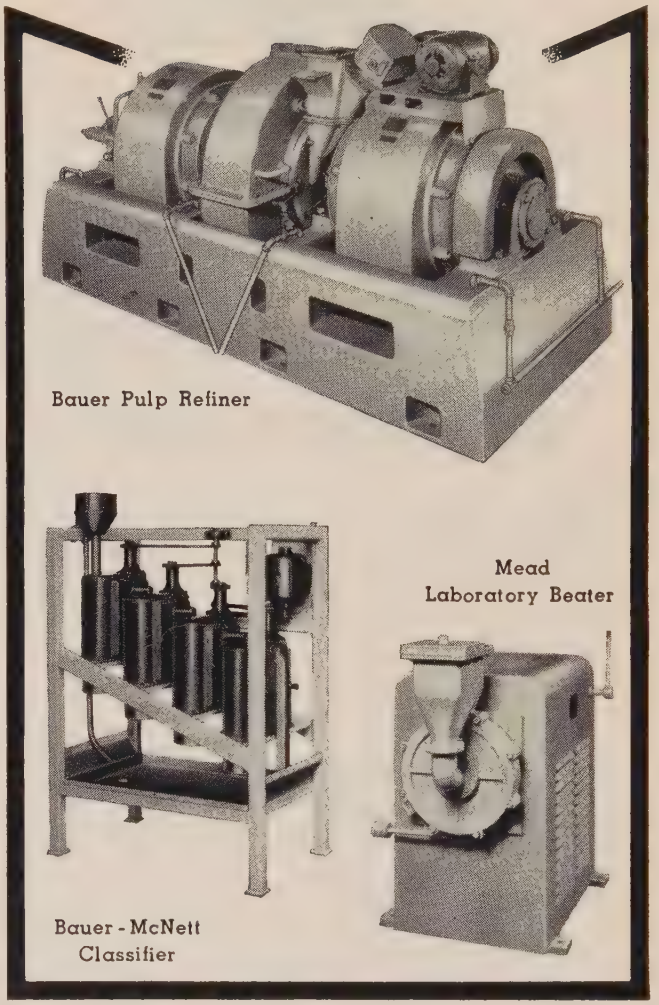

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The System Cellulose–Sodium Hydroxide–Water. Determination of the Ionization Constant of Cellulose

JOHN B. CALKIN

With the existence of compound formation between sodium hydroxide and cellulose established, it is possible to express the ionization constant of cellulose as an acid. By use of the thermodynamic equation of colloidal membrane equilibrium, the apparent ionization constant of various forms of cellulose in the system cellulose–sodium hydroxide–water has been determined experimentally. Cellulose in different forms has been brought to equilibrium in various sodium hydroxide solutions with exclusion of air. The results of the work may be summarized as follows: (1) using the Donnan membrane equilibrium and based on certain implicit assumptions, a derivation for the determination of the apparent ionization constant of cellulose is given; (2) it has been shown that the apparent ionization constant of cellulose differs with alkali concentration; (3) the apparent ionization constants for different types of cellulose are given; (4) the apparent ionization constant of cotton pretreated with caustic soda is shown to increase with increasing concentration of caustic soda used for pretreatment; (5) theoretical considerations are in accord with the experimental fact that the apparent ionization constant may vary with the concentration of the sodium hydroxide solution.

Sorption studies with sodium hydroxide solution and cellulose (*2*) have been correlated previously with x-ray results (*4*) and with the Phase Rule (*1*). Now that the existence of the compound formation between sodium hydroxide and cellulose has been established (*4*), it is possible to express the ionization constant of cellulose as an acid.

The thermodynamic equation of colloidal membrane equilibrium due to Donnan (*7*) and Donnan and Harris (*8*) has been successfully applied to the swelling of gelatin in dilute acid by Proctor and Wilson (*14*). The latter suggested that their theory might be applied to other colloids. Minor (*10*) has reviewed and discussed Loeb's "Donnan Membrane Equilibrium Theory" in its relation to the reactions of papermaking. Sacks (*16*) states that the Donnan membrane equilibrium underlies dyeing processes. Neale has investigated (*11*) the application of the thermodynamic equation to the system NaOH–cellulose (the cellulose being in the form of regenerated sheet cellulose known as cellophane) and finds that at low concentrations (below approximately 1.2 molal) the alkali sorptions are seriously below those calculated. This finding, together with his determination that the heat of reaction of cotton is below that for regenerated cellulose, he ascribes to what he calls "accessibility" or a sort of steric hindrance, the gel being insufficiently swollen in the case of regenerated cellulose at low concentration and of cotton cellulose to allow the acidic groups to be "accessible to alkali." Neale (*12*) has determined the ionization constant of the regenerated cellulose used as 1.84×10^{-14} at 25°C. below 0.5 molal sodium hydroxide solutions. Rabinov and Heymann (*15*) state that "the ratio X of the volume of the cellulose phase to that of the solution phase . . . not only introduces uncertainty about the numerical value of K, but makes it very doubtful whether it is at all possible to express the behavior of the cellulosic acid in terms of a dissociation constant. The value of X is not only doubtful in regard to its absolute magnitude, but it will also increase with decreasing concen-

John B. Calkin, Director, Department of Industrial Cooperation, and Associate Professor of Chemical Engineering, University of Maine, Orono, Me., and Chemical Consultant, New York, N. Y.

tration, since the thickness of the ionic atmosphere increases with decreasing concentration. Application of the theory of the diffuse double layer as well as generalization of the theory of strong electrolytes both lead qualitatively to this assumption. The result is a variation of the dissociation constant with the salt concentration. Such behavior is not surprising, since the system investigated is in some respects similar to an ordinary electrolyte with strong interionic forces. That these make themselves felt, although the cellulosic acid behaves as a weak acid, is due to the extremely high valency of the anion of the cellulosic acid."

DERIVATION OF THE EQUATION FOR EXPRESSING THE IONIZATION CONSTANT OF CELLULOSE

Based on certain implicit assumptions, which will be discussed later, equations are derived which permit the expression of certain constants for cellulose in solution. These have many of the characteristics of the ionization constants. For the sake of brevity the activity coefficients have been omitted in the derivation, but do appear in the tables of data.

Let

$$[Na^+] \text{ inside} = y \tag{1}$$

and

$$[OH^-] \text{ outside} = x, \text{ then } [Na^+] \text{ outside} = x \tag{2}$$

Then by definition Donnan's equilibrium is expressed by

$$x^2 = y[OH^-] \text{ inside} \tag{3}$$

For electrical neutrality

$$[Na^+] \text{ inside} \cong [A^-] + [OH^-] \text{ inside} \tag{4}$$

Let

$$[A^-] = z \tag{5}$$

Then

$$y = z + [\ OH^-\ ] \text{ inside} \tag{6}$$

$$[OH^-] \text{ inside} = y - z \tag{7}$$

which substituted in (3) gives

$$x^2 = y(y - z) \tag{8}$$

Dissociation of cellulose acid

$$H^+A^- \rightarrow H^+ A^- \tag{9}$$

$$= (w - z) \text{ where } w = \text{mols } HA\text{(cellulose)} \tag{10}$$

Then, for equation (9), one can write

$$[H^+]z/(w - z) = K_A = \text{the acid ionization constant of cellulose} \tag{11}$$

Therefore, in view of equation (7)

$$K_W z/(y - z)(w - z) = K_A \tag{12}$$

where

$$K_W = [H^+]\,[OH^-] = \text{ionic product for water} \cong 10^{-14} \tag{13}$$

Eliminating z through the use of equation (8), we obtain from equation (12)

$$K_A = K_W(y/x^2)\,(y^2 - x^2)/(wy - y^2 + x^2) \cong 10^{-14}\,(y/x^2)(y^2 - x^2)/(wy - y^2 + x^2) \tag{14}$$

Computations of the ionization constant are made by substitution of the experimental data in equation (14).

EXPERIMENTAL PROCEDURE FOR SHEET MATERIALS

Neale (*11*) has worked out a method whereby he immerses small sheets of cellophane in solutions of sodium hydroxide, and after the material has been conditioned to equilibrium

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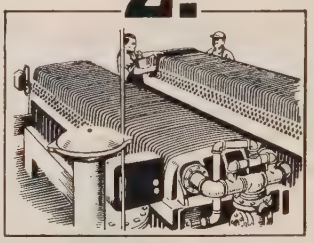

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at a given temperature the cellophane is removed from the solution, placed between blotters, thus removing the excess solution from the sample. The swollen sample is then weighed, the NaOH determined by titration, the cellulose washed free from salt and dried to obtain the moisture-free weight of cellulose. The water is then obtained by difference.

For the derivation given above it is necessary to calculate the inside molality of sodium hydroxide and the mols of cellulose per 1000 grams of H_2O from these data. The molality of the sodium hydroxide solution in equilibrium with the sample is determined by titration.

EXPERIMENTAL RESULTS ON GLASSINE AND CELLOPHANE

As glassine is a sheet material, in which the beating has reduced the fibrous structure to a considerable degree, it was considered that the above method of Neale's for cellophane would also be applicable to glassine. Pfeffer (*13*) has determined the ionization values for cellophane and glassine in solutions down to approximately 0.5 molal. Using the same samples and Neale's procedure, the range has been extended to lower dilutions at 25°C. in Tables I and II. The experimental data extending Pfeffer's work to lower dilutions are given in Table I for cellophane and Table II for glassine. Both Pfeffer's work and the results reported in this paper were carried out in small flasks or weighing bottles with greased, ground glass stoppers to minimize oxidation. There was a small free space above the liquid although the effect of oxygen was at a minimum.

In Table III are shown the characteristics of glassine and cellophane.

CALCULATION OF APPARENT IONIZATION CONSTANTS OF VARIOUS TYPES OF CELLULOSE FROM DATA IN THE LITERATURE

Using the data of Coward and Spencer (*5*), Neale (*11*), and Bancroft and Calkin (*3*), and equation (14), the ionization constants have been determined by plotting. The values from the slope of the curves are given in Table IV.

DISCUSSION OF RESULTS

In considering the application of the Donnan membrane

Table I. Apparent Ionization Constant of Cellophane in Dilute Solutions at 25°C.

Calculated from experimental data			*Calculated values for derivation*[a]			
Outside end concn., X, mols NaOH per 1000 g. H_2O	*Inside concn., Y, mols NaOH per 1000 g. H_2O*	*W, mols of cellulose per 1000 g. H_2O*	$\frac{wy'y}{(y'y)^2 - (x)^2}$	$\frac{y'y}{(yx)^2}$	*True preferential absorption,* $\frac{y - x}{w}$ *mols NaOH/mol cellulose*	*"Ionization constant," K_A, equation (14)*
0.314	0.784	4.19	9.35	10.12	0.1122	1.21×10^{-14}
0.0926	0.269	4.81	27.9	35.0	0.03665	1.30×10^{-14}
0.1015	0.320	5.74	27.35	35.0	0.0381	1.33×10^{-14}
0.00873	0.0342	6.1	221.0	460.0	0.00418	2.09×10^{-14}

[a] Activity coefficient data for sodium hydroxide solutions are from Ferguson and Schluchter, *Trans. Am. Electrochem. Soc.* 52: 363 (1927); see also Harned, *J. Am. Chem. Soc.* 47: 676 (1925) and Lewis and Randall, "Thermodynamics," 1923, pp. 352–353.

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Table II. Apparent Ionization Constant of Glassine in Dilute Solutions at 25°C.

Calculated from experimental data: Outside end concn., X, mols NaOH per 1000 g. H_2O	Inside concn., Y, mols NaOH per 1000 g. H_2O	W, mols of cellulose per 1000 g. H_2O	Calculated values for derivation: $\frac{wy'y}{(y'y)^2 - (x)^2}$	$\frac{y'y}{(yx)^2}$	True preferential absorption, $\frac{y - x_1}{w}$, mols NaOH/mol cellulose	"Ionization constant," K_A, Equation (14)
0.313	0.487	5.95	30.6	6.46	0.0292	0.22×10^{-14}
0.1091	0.1822	7.24	83.3	17.99	0.0101	0.22×10^{-14}
0.0089	0.0292	7.61	333.0	381.0	0.002665	1.15×10^{-14}

equilibrium to the system cellulose–sodium hydroxide–water, it must be borne in mind that the mechanism portrayed by the derivation given previously is not as simple as that given because of several implicit assumptions. The application of the Law of Mass Action is based on a homogeneous solution and we do not have such a solution. In considering the present system, we must bear in mind that the solution is not a homogeneous one as there is the surface action of the cellulose with molecular chains surrounded by solution. Further, no account has been taken of the activity coefficient of the cellulose as the system contains a high concentration of cellulose even at low concentrations of sodium hydroxide solution. It is well to bear these assumptions clearly in mind.

In studying the data presented, it will at once be evident that certain facts stand out;* i.e., (1) that the ionization con-

Table III. Characteristics of Cellophane and Glassine

	Block density (air-dry), g./cm.³	Porosity, sec. for 50 cc. of air to pass through sheet[a]
Glassine	1.33	4800
Cellophane	1.68	No passage of air up to 262,800 sec.

[a] Porosity measurements on new type Gurley densometer by courtesy of the Dennison Manufacturing Co.

* Heuser has pointed out (private communication) that the question arises whether "hydroxyl acidity" is not interfered with by that acidity of cellulose caused by the presence of carboxyl groups. He suggests that measurements of the ionization constant should be made only with samples in which all the free carboxyl groups have been allowed to combine with cations in much the same way as employed by Harris and co-workers in their determination of the "base binding capacity" of cellulose. The author believes this is a valid criticism and considers that it would be advisable to compare the results with or without active carboxyl groups.

Table IV. Apparent Ionization Constants of Various Types of Cellulose at 25°C.

Type of material	$K_A \times 10^{-14}$	Investigator
Cellophane	0.946	Neale
Cellophane	0.82	Pfeffer
Glassine	0.210	Pfeffer
Cotton	0.429	Coward and Spencer
Standard cotton[a]	0.215	Bancroft and Calkin
Standard cotton 2.9 molal NaOH pretreated	0.345	Bancroft and Calkin
Standard cotton 5.44 molal NaOH pretreated	0.694	Bancroft and Calkin
Viscose rayon 1	0.946	Bancroft and Calkin
Viscose rayon 2	0.946	Bancroft and Calkin

[a] Prepared according to A.C.S. Method (*Ind. Eng. Chem.* 15: 748 (1923)).

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stant varies with alkali concentration, (2) that the ionization constant is different for different types of cellulose, and (3) that caustic pretreatment increases the ionization constant.

The ionization of cellulose could occur from any one of the positions of the —OH groups; i.e., 2, 3, or 6-position (*6, 9*) or on an end group. Spurlin (*17*) has concluded that:

> "The available experimental evidence is entirely in harmony with the viewpoint developed . . .; namely, that the substituents in a cellulose derivative are distributed among the hydroxyls according to the laws of chance, and the three sorts of hydroxyls are substituted to an extent relative to one another that is determined by the relative reactivities of the hydroxyls (determined by their inherent properties as well as by the reaction medium) and the nature of the reaction (proceeding to an equilibrium at a partially substituted state, or with a tendency to proceed to complete substitution, but stopped at a partially substituted state)."

RESULTS

The results of this paper are as follows:

1. Using the Donnan membrane equilibrium and based on certain implicit assumptions, a derivation for the determination of the apparent ionization constant of cellulose is given.
2. It has been shown that the apparent ionization constant of cellulose differs with alkali concentration.
3. The apparent ionization constants for different types of cellulose are given.
4. The apparent ionization constant of cotton pretreated with caustic soda is shown to increase with increasing concentration of caustic soda used for pretreatment.
5. Theoretical considerations are in accord with the experimental fact that the apparent ionization constant may vary with the concentration of the sodium hydroxide solution.

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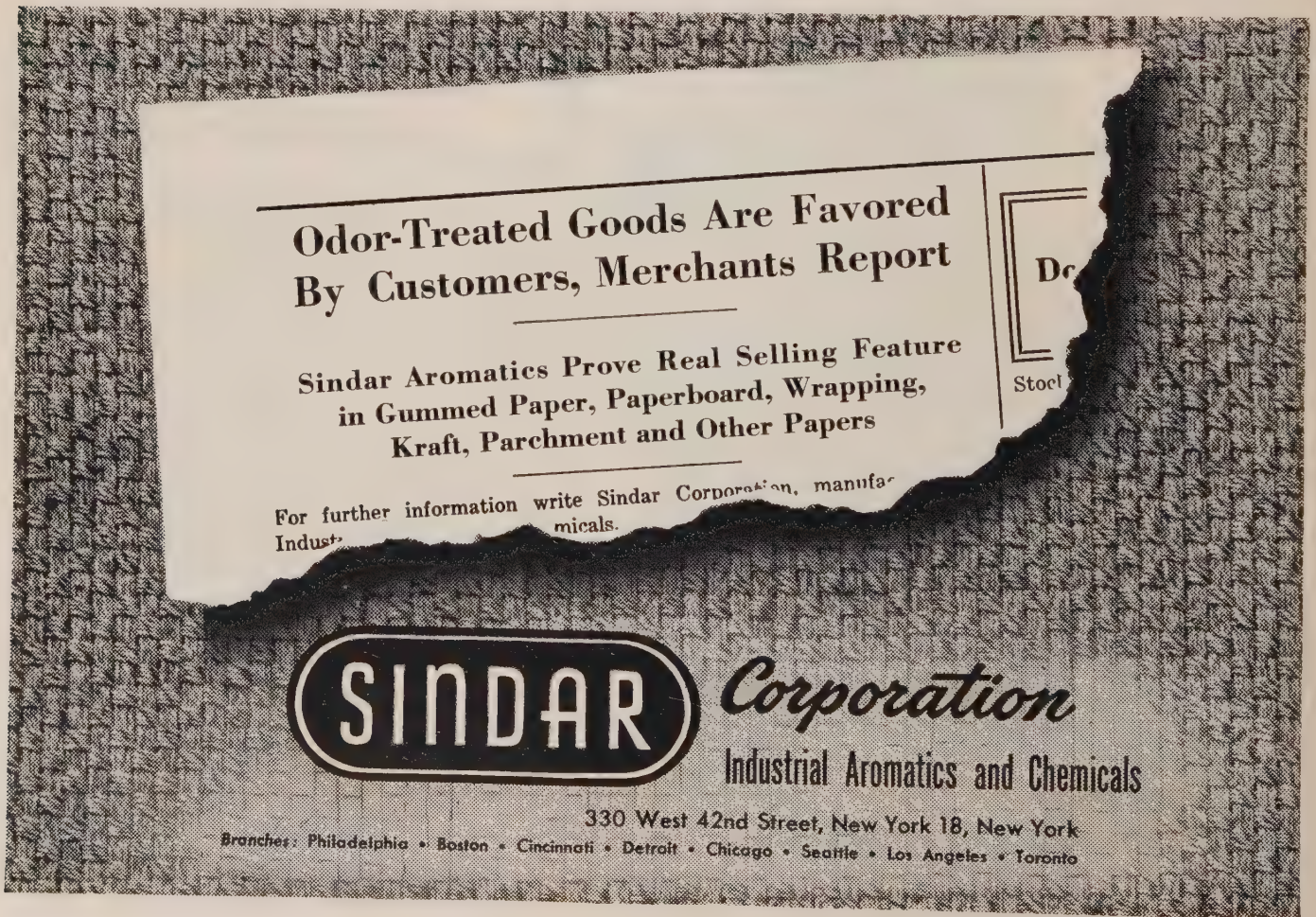
Presented at The 119th Annual Meeting of the American Chemical Society, Colloid Division, Boston, Mass., April 4, 1951.

Paper and Board Characteristics That Affect Inks and Printability

L. F. ENGELHART

With the exception of that used in building materials, almost all varieties and over half of the huge output of paper and board are printed in some fashion or other. Publications, packaging, and containers account for most of this printing which may range from some 90% surface coverage in single or multicolor to mere "handle with care" or "this side up" one-color imprints on fiberboard shipping cases.

L. F. Engelhart, Head of Eastern Products Development Laboratory International Printing Ink, New York, N. Y.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PRINTABILITY

Having agreed that printability is important, the next logical step seems to be to specify it. This is where we may not agree. I cannot adequately define it—let alone scientifically specify it.

One reason is that printability is not always something that comes in a can, or even in a sheet—though we hope it does. It is like that bug-a-boo in calculus—a variable that is a function of, and dependent on, other variables such as: ink, stock, printing process, press, plate, job, atmospheric conditions, and sometimes the condition of the pressman, himself.

Hence, to answer such questions as "how will it print?", or even "how does it print?", we have to use relative rather than absolute terms.

Even so, ever since papermakers have adopted oil absorption tests in lieu of water penetration, and tack graded inks instead of wax for "pick" tests; and, inkmakers have used Inkometers and fineness-of-grind gages instead of finger tapouts and glass smears—both have been able to design or formulate their products to rather rigid empirical specifications that generally extrapolate to good printability when there is cognizance of the printing conditions the respective products have had to meet.

The printer has been very cooperative with the inkmaker in this respect, and regularly supplies samples of the stock that he intends to use, as well as pertinent information relative to the expected application conditions and end usage. The inkmaker, before they come out with some new ink or process, beg, borrow—or sometimes even purchase—sufficient stock for semicommercial trial. I imagine you and the printer frequently have some such similar pretest arrangement.

I think this all points out that printability may be a somewhat nebulous property, and that unless we feel we are somewhat clairvoyant, we had better make some tangible pretest prints of our own, before the printer gets into a "jam" with something that we, and he, expected to be printable.

It is the purpose of this discussion to list and discuss the paper and board characteristics that affect inks and printability, and to suggest, if possible, how these characteristics should vary to best suit the generally used printing processes. The chances of good printability performance seemingly depend upon these characteristics or properties and their degree or how they are varied in relation to the inks, the printing process, and even the particular job to be run.

It is usually only after the printer and inkmaker have been unable to adjust the ink, printing variables, and job to the paper on hand, that the paper expert is consulted—and then, unfortunately, it usually results in the paper either being used on another job—or if not in a "shortage era" the paper is actually rejected and returned to the mill.

Even so, drastic as this may seem, all concerned are probably lucky that this unhappy paper-ink-printing relationship has been discovered before the job has been run for the printer has to spend a lot of his own time and money on a printed job, and if it is rejected by his customer it may cost someone far more than merely the price of paper and ink used.

Hence, it is in an endeavor to prevent or minimize such occurrences that we stress what we think are the characteristics that govern printability, as follows:

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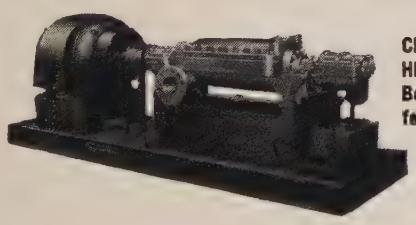
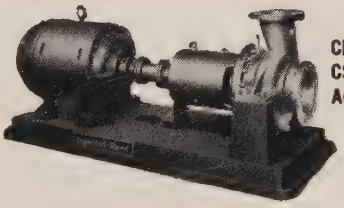
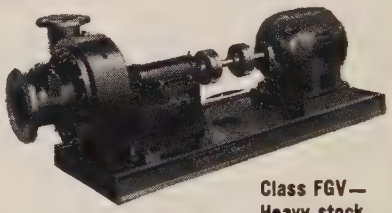


Class HMTA—Boiler feed



Class CSFL—Acid



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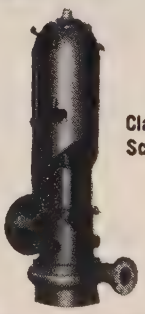
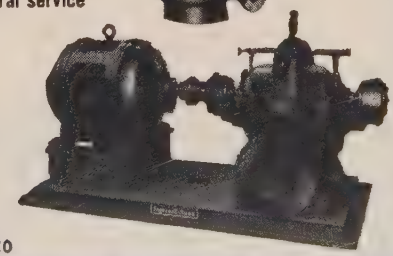


Class VGV—Screened stock

Class ALV—White water and general service



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1. Surface Smoothness (Felt and Wire Side)
   a. Initial smoothness.
   b. Smoothness under impression (ultimate smoothness).
      (1) Compressibility.
      (2) Resilience.
      (3) Uniform thickness (caliper).
2. Ink Receptivity and Affinity (Felt and Wire Side)
   a. Surface porosity or permeability to ink and oil.
      (1) Initial during instant of impression (pressure may close pores).
      (2) Ultimate—or rate of after-impression until ink is dry. Body voids and capillaries here may be a factor as well as the surface.
   b. Surface wettability to ink or oil. Low contact angle to ink and/or its vehicle—must not "repel" same. Together with porosity, smoothness and pressure govern "ink transfer."
3. Surface Strength or "Pick" Resistance (Felt and Wire Side)
   a. At normal moisture content ranges (4 to 6%) and humidities.
   b. When surface is moistened—as in lithography.
4. Color and Surface Reflectance (Felt and Wire Side)
   a. Hue—white, tinted, or colored: brightness if white or near-white.
   b. Cleanliness—absence of specks, etc.
   c. Specular reflectance or "finish" and uniformity of same.
5. Opacity
   a. Actual opacity relative to "show-through."
   b. Opacity in relation to ink penetration or "strike-through."
   c. Density—caliper and substance weight which are indirectly associated with most all our characteristics are listed here for want of a better place.
6. Dimensional Stability
   a. Hygroscopicity—hygroexpansivity or shrink in varying relative humidity.
      (1) Expansion.
      (2) Contraction.
      (3) Curl.
   b. Distortion under mechanics of printing and subsequent processing.
      (1) Impression.
      (2) Web tension.
      (3) Folding.
      (4) Binding.
      (5) Die-Cutting, etc.
7. Body Strength
   Physical or mechanical strength (other than pick) in relation to the mechanics of the printing process
   a. Tensile.
   b. Fold.
   c. Tear.
   d. Burst.
   e. Rigidity (for sheet feeding).
   Caliper and substance weight are, of course, other specifications that other things being equal—have direct influence on body strength.
8. Chemical Reactivity (Felt and Wire Side)
   a. Surface pH and reactivity vs. litho fountain solution and aluminum and zinc plates.
   b. Surface and body pH and reactivity re ink oxidization, driers, etc.
   c. Chemical corrosion of metals used for letterpress or gravure plates.
9. Surface Abrasiveness (Felt and Wire Side)
   Physical or mechanical erosion tendencies for the printing form or plates in whatever process used.
10. Fiber Orientation (Grain) and Formation. (This characteristic is ordinarily not listed as a physical property in the same category as the above, since it is not numerically measurable—but neither is "printability," and it has such influence on same it is listed as another major characteristic.)
    a. Grain direction—degree of such orientation. Direction to be specified—usualy to run the long way of the sheet.
    b. Order of formation—as uniform, well-felted, irregular, or "wild."
11. Moisture Content. (This may not be a part of built-in composition or structure but is most important to the printer.)
    a. Percentage moisture content. To be specified so as to be in equilibrium with printing conditions. Such content and/or equilibrium, influences:
       (1) Curl, wave, dimensional stability (register).
       (2) Mechanical strength and plasticity of stock.

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(3) Drying rate of oxidizing and moisture-set inks.
(4) Brittleness or blistering with heat dry inks.
(5) Static.

12. Uniformity

Having established the foregoing 11 characteristics suitable to a given printing and process, these properties are to be uniform sheet-to-sheet, skid-to-skid, roll-to-roll, lot-to-lot. Caliper and substance weight are important purchasing specifications which must likewise be kept uniform. Also, two-sidedness (or difference between wire and felt) should be kept to a minimum.

At the same time, the printer expects the absence of external damage and internal faults, and the other following conditions in his received stock:

Sheets: Grain direction marked, felt side up, preseasoned and moistureproof wrapped, sheets flat and trimmed square.

Rolls: Felt side marked; tightly and evenly wound on firm core; absence of poor splices, slime spots, pinholes, and scorch spots; hard undamaged edges.

Both types are to be free of fuzz, lint, and cutter or slitter dust.

Papermakers should know what compositions and processings govern or control the foregoing characteristics which, it seems to me, are of major importance in their effect on the printability of paper or board.

Hence, I will merely list what I think are the proprietary items or processings in this respect. These are: the degree of beating and refining; the formation on the paper or cylinder machine; the degree and type of beater sizing used; the tub sizing, if any; the type and amount of filler, if any; the amount of calendering; the nature of the coating, its weight, and method of application; the moisture content left in the finished board or sheet; and, of course, the speed of your machines and price range of your products.

It is obvious that I have listed practically all the more important papermaking variables, as all of them seemingly contribute in fairly important degree to these characteristics and, consequently, your products' suitability to one or another of the most-often-used printing processes. As to which of these papermaking factors are the most important, and to what degree they govern the listed characteristics—I would rather have you tell me—my knowledge in that respect is all second-hand.

Of course, if we divide paper and board properties into two basic groups, such as: (1) surface, and (2) internal characteristics, then I feel reasonably sure the former are the more important in their effect on printability, and that the degree to which your papermaking factors influence surface, determines their ratings in relation to printability. I would like to enlarge upon surface and ink-film relations as follows:

SURFACE AND INK FILM RELATIONSHIP

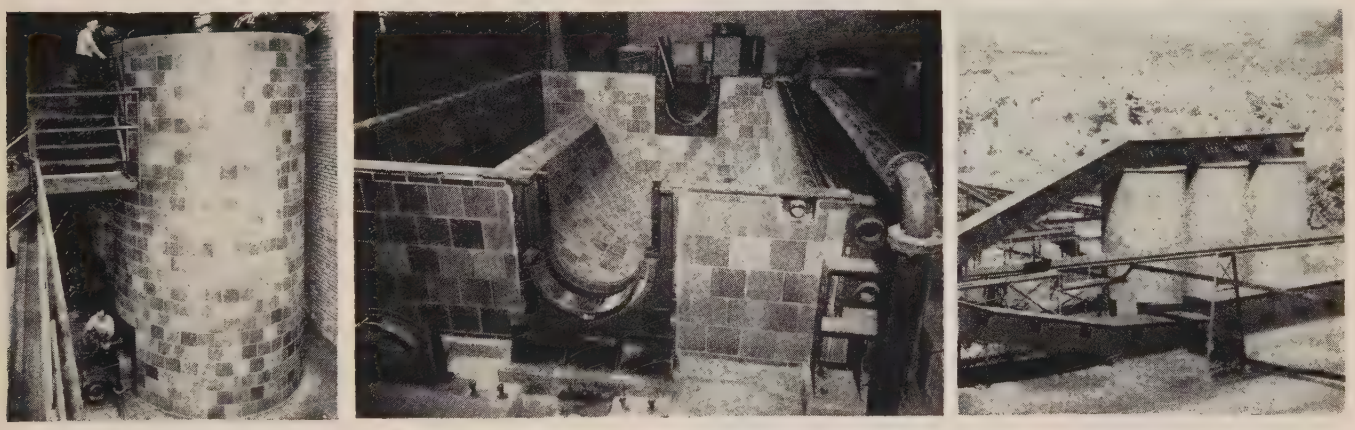
If we use the rough two-way classification, we find that in his general work the printer is most interested in, and concerned with surface characteristics.

The internal paper or board properties are usually only important to him insofar as they affect the surface properties and the mechanical efficiency with which they carry those surfaces through the feed, register, ink transfer, and delivery operations at the given speed of printing.

Now in all printing or reproduction work involving halftone or screen printing where tonal gradation is accomplished by printing tiny dots, the paper or board deposited ink film is exceedingly thin. Whether this screen printing be by letterpress, offset, or gravure, these wet ink films are only of the order of 0.1 to 0.2 mil in thickness.

These are considerably thinner films than even the lightest weight coatings—as say, on a machine coated publication paper—where the minimum one-side coating would be of the order of 6 pounds per 25 × 38 ream. For example, on equivalent basis such ink-film coating, in solid coverage, would run from 2 to 3 pounds per similar ream.

I use these rough data to illustrate how thin the ink film is



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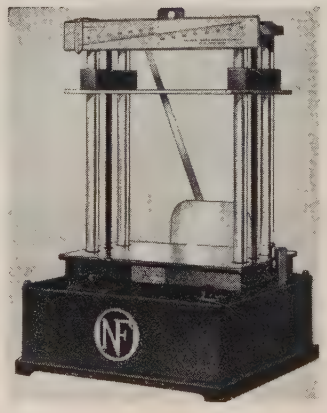

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in relation to the bulk cross section of even the thinnest papers and coatings. It shows why the printer must concern himself principally with the surface; he just has not enough ink film to waste squeezing deep into the body stock, and usually has trouble enough pressing down, leveling, or "bottoming" (as in impression) the surface irregularities to adequately cover the hills and valleys of the surface of the sheet.

I think if you keep this thin film-ink relationship in mind, you will better appreciate the emphasis on the surface characteristics in my listed paper board characteristics. I hope to once more cover this list, this time stressing their relationship to practical printing and ink application—or printability, in general, which is a composite or total result of these many different, and mostly surface, characteristics.

SURFACE SMOOTHNESS AND TEXTURE

In general, the smoother the surface the better the printing. To the printer who must print fine line and fine screen in all phases of high-quality letterpress and gravure reproduction work, surface smoothness, under normal printing impression, is probably the single most important characteristic governing the printability of the web or sheet.

The optics and mechanics of the important printing processes necessitate that, in both single and multicolor work, tonal gradation be accomplished by breaking continuous tone into tiny discontinuous printing areas, cells, or dots. Likewise, the finer this dot or screen structure, the finer is the possibility of detail and fidelity of reproduction in comparison to the original.

Furthermore, the smoothness of the paper in relation to this screen fineness should be such that every dot or cell from the plate prints or transfers onto the paper being printed. If any of these dots are missing, or even imperfectly transferred, they detract from this quality and fidelity of reproduction. Even though the individual dots or imperfections of same may be invisible to the naked eye—their total assembly integrates into an effect wherein any such shortcomings are readily noticeable.

It is obvious how surface texture or lack of smoothness may mutilate these dots and, hence, that the smoother the sheet, the finer the permissible dot structure. In fact, the following table showing the practical screen fineness limits for the average of various papers used in letterpress printing is a good illustration of this point.

Stock	*Maximum screen fineness*
Number 1 enamel	150–175
Dull finish coated	120–133
Machine finish coated	110–133
Super and English finish	100–120
Machine finish and book	85–110
Bond and ledger	85–100
Newsprint	55–85

Likewise, it is the surface smoothness or regularity under pressure that is the real characteristic that determines such smoothness to the printer. You may have heard of "kiss impression" as used in printing. Actually, there is little or no "kiss" in any of the commercial printing work or processes. If plates, printing, and make-ready in letterpress were accurate to tenths of a mil, instead of several mils, and optically smooth or level stock was available, then "kiss impression" might not be a misnomer.

Actually, the printer makes ready to just mere "kiss" or contact—and then adds one or several sheets more squeeze to compensate for "form" and paper surface irregularities. He thus ends up with some 4 to 10 mils impressional squeeze in metal plate letterpress, and from 3 to 5 mils blanket pressure in offset application.

Translated into terms of pounds pressure per square inch, this is still quite a controversial subject noted for its dearth

of data—but my present guess is that, in the various processes, they will often range somewhat as follows:

Offset	50 to 150 p.s.i.
Metal plate letterpress	200 to 600 p.s.i.
Rotogravure	300 to 1000 p.s.i.

Even granting some of these data may be far "off," the general order is one of rather terrific pressure peak, much of it being necessary to iron down or "bottom" the paperboard surface irregularities, so as to affect total paperink contact and complete coverage on the final print. Hence, you can see the importance of any initial or impressional smoothness, compressibility, resilience, or uniform caliper, in determining the amount of such pressure needed—and that a minimum of such pressure will lessen chances of fill-in, squashing of the dot, undue press strain, punching of packing, and plate wear.

Before leaving surface smoothness, I should mention that one boon to the printability of paper and board of comparatively low order of such smoothness, is the ability of certain printing processes to print from resilient plates or surfaces so as to effect better coverage on same.

The use of rubber or elastomeric plates in the letterpress printing of corrugated board, the rougher fiberboard, and kraft, illustrates such coverage. Here, we have what might be called printing with "ink" instead of "pressure," as the ink films used are many times thicker than that of publication printing—which together with the resiliency of the plate permits coverage of the rough surface and low spots. The nature of the printing, however, is confined to heavy line and solids with, of course, no screen.

On the other hand, in offset printing from a rubber blanket, even fine screens can be used on relatively rough or even embossed surfaces. Since heavy films cannot be "carried" due to plate and transfer limitations of the process, it finds more usage on rough papers than rough boards.

Aniline printing is particularly adopted to rough surface boards and papers for reason that its rubber plates and great fluidity of ink enable it to wet and cover low spots, and its quick drying by evaporation allows the use of heavy films on such stock without danger of set-off.

In summation, however, remember the highest reproductive or pictorial qualities are only obtained by the use of the finer screen printings (as 120 and over) and, except for offset, such screens need the smoothest of surfaces such as the highest grade coated papers. Furthermore, for this smoothness of surface reasons, even the cheapest coated papers normally print better than the best of the uncoated supercalendered papers, and for this reason the lightweight machine coated stocks are replacing uncoated papers in practically all large volume quality publications.

INK RECEPTIVITY AND AFFINITY

Relative ink receptivity in speed, degree, evenness, and ease of ink absorption ranks with surface smoothness as probably being the generally most important characteristic governing printability. Such tests, particularly if made with a precision proof press, will tell whether the paper has any hard spots and is likely to promote "strike through" on the one extreme—or "set-off" on the other. At the same time, these absorption or receptivity characteristics indicate whether or not you may expect gloss or matte finish; smooth or mottled and speckled lay; easy or difficult wet trapping; stick or nonsticking in the pile; and frequently fast or slow drying with the usual or conventional range of printing inks.

The initial penetration which is entirely a function of ink to paper-surface relationships and when under printing pressures of from 50 to hundreds of pounds per square inch lasting from $^1/_{10}$ to $^1/_{500}$ second (depending on the press speed) may be distinctly different from subsequent or ultimate penetration. Later, after this pressure has been released, and the ink vehicle has had time to reach some of the interior of the

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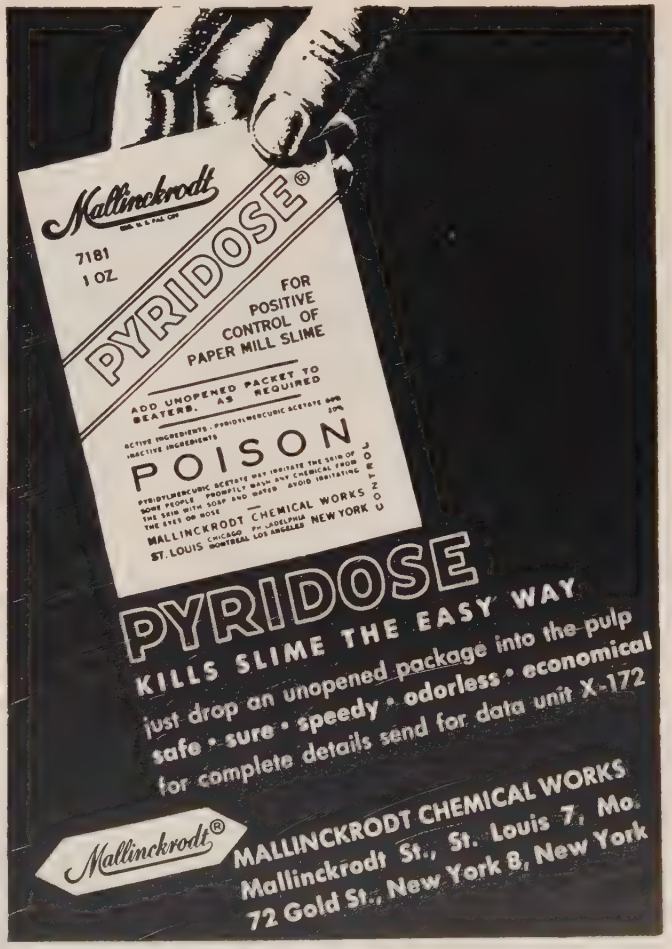

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stock, different, and possibly more selective capillary actions may take place.

SURFACE STRENGTH OR "PICK" RESISTANCE

The surface strength or pick resistance is the third and last of the three paper or board characteristics that essentially dominate the actual mechanics of the ink transfer from plate to stock, which operation is the crux of all printing.

Of course, surface strength does not physically aid ink deposition, or transfer, to the extent as does surface smoothness (which allows contact) and receptivity (which with pressure keeps contact). But, if of sufficient magnitude, it permits the final act of transfer by allowing the ink film to split or separate away from the plate at the given speed of printing, without surface rupture or pick of the paper itself.

Adequate surface bonding or pick resistance is particularly important in these days of high-speed printing because it is a simple physical law that the "pull" of an ink on paper is increased directly with the speed at which the paper leaves the inked plate.

Furthermore, for satisfactory trapping in all multicolor wet printing, it is necessary for the inkmaker to progressively tack grade his inks from first to last-down color. This means that in four-color work, the first-down ink or color has to be appreciably tacky to "foundation" the subsequent colors—and at a thousand feet per minute or more printing speeds, will exert considerable pull on the paper surface. Likewise, heavy forms, and the increasingly popular gloss inks, require high orders of such pick resistance.

Now in the lithographic offset process of printing, all the foregoing pick resistant requisites must be met with—but, in addition, when the surface is moistened with a thin film of water or fountain solution. In such printing, there is over-all contact of the paper surface by a moist rubber blanket. This moisture on the blanket first hits the surface of the fresh sheet or web at the instant of the first color impression—hence, in this case, and in single color impression, probably has not much time to accomplish much softening on the surface.

However, in multicolor printing—subsequent ink and moisture films again, and again, up to three additional times, hit this same sheet's surface. Hence, by the time these later impressions take place, moisture and fountain acid have had a good chance to soften and weaken the film or coated surface. Add to this, the fact that litho inks must usually be inherently more tacky than other inks—and you can readily realize why you must be so careful in the surface bonding of stocks for such type of printing.

Evidence of the severity of these antipick requirements in this lithographic process is that, so far, you papermakers have been unable to furnish a coated paper surface that will permit the offset web printers to use the full speeds of what their newer presses are capable. They presently have to run at slower speeds with frequent stops and blanket wash-ups, when running these coated papers.

While on the subject of surface strength and pick, I think I should remind you that my company has developed a series of standard tack graded inks and procedure of proof-pressing with same, that seemingly gives a practical means of evaluating the pick resistance of paper and boards, as well as certain other of the hard-to-measure printability characteristics.

COLOR AND SURFACE REFLECTANCE

There is no need for going into much detail relative to these characteristics. These properties can be scientifically measured and specified, and have been used as purchasing yard sticks for many years.

One thing to remember, from the printing viewpoint, is whiteness and brilliance are paramount in high-order four-color process printing. In such reproduction, transparent inks must be used, as superimposition is just as important as dot or color juxtaposition in effecting the spectral range needed

to facsimile reproduce the original. Here, we need a high brightness and clean white to reflect from the sheet through the ink films in order to get the necessary hue and saturation of color for perfect reproduction.

Furthermore, in single color reproduction such as black and white, we need the same whiteness to give maximum contrast and tonal range since the unprinted spaces between the dots or lines permit, as has been said, "the paper to become part of the picture."

OPACITY

Here, too, is another characteristic that can be precisely measured—as by contrast ratio or other optical means. This property has particular significance to the printer, and ultimate user, in cases of two-sided printing where "show through" of reverse-side printing would be highly objectionable to all concerned. Together with porosity and substance weight, it is also a major factor in "strike-through," wherein the ink vehicle penetrates so deeply as to stain or transparentize the sheet. Titanium dioxide or calcium carbonate, as filler or coating component, as well as formation, have done wonders in opacifying the thin and lightweight papers in the publication, Bible, book, and wax-wrap fields.

DIMENSIONAL STABILITY

Hygroscopicity: Paper absorbs or gives off moisture which changes in relative humidity—which classifies it as a hygroscopic material. These changes in the hygroscopic moisture content of the sheet are always accompanied by dimensional changes which are a bane to all printers and printing processes, as they are the basic causes of most misregister, distortion, curling, feeding, folding, and even sheet delivery troubles.

Grain will be taken up under separate heading, but it is not uncommon for a dense sheet (as used in lithography) to expand or contract about $^1/_4\%$ in the across-the-grain direction with as little as 1% moisture change. This means some $^1/_{10}$-inch dimensional change on the back edge (away from the gripper) of some fair-sized printing sheets.

Close register is absolutely essential to the production of acceptable multicolor work. When they ask for "hair-line register," they literally mean it and expect superimposition with only $^1/_{100}$ inch, or less, leeway. Even the average public, who is many times the least critical of printing quality, takes immediate notice of misregister in illustration work, and is by far the most cognizant of this over all other printing shortcomings. This is natural in that only one of a set of four-color plates need be slightly out of register to "blur" the whole ensemble, give loss of most detail, and spoil the whole of a pictorial reproduction. Many letterpress news comics and gravure Sunday supplements typify such faults.

Mechanical distortions due to pressures, tensions and strains inherent in the printing process, as well as residual processing strains left in an unseasoned sheet, likewise, but to a lesser degree, adversely affect register, feeding, folding, die-cutting, trimming, pasting, binding, and other adjunct-to-printing operations.

All in all, it can be seen that dimensional stability is a very important, even if indirect, printability property.

BODY STRENGTH

Since these characteristics are more related to internal rather than surface characteristics, they are not as important to ink and actual printability as most of the other listed properties. The methods by which the strength of a paper is tested in the mill do not express its suitability for printing purposes. However, the sheet or web should have sufficient of these strength characteristics to satisfactorily pass all the mechanical operations of feed, unwind, register, delivery, rewind, folding, and binding connected with printing.

In addition, of course, the strength properties must be suited to the ultimate use requirements of the printed stock. Hence, even though it is to be printed for decorative or dis-

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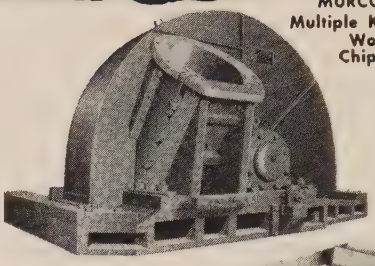

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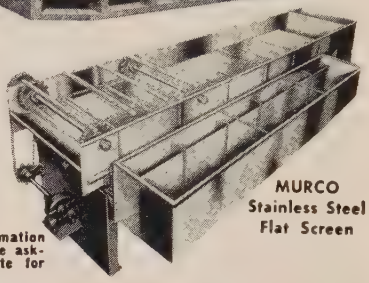

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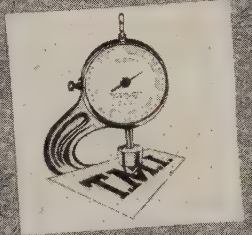

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play purposes, if the stock ultimately has to be used for cover, wrapping, packaging, container or protective purposes, it must have sufficient tensile, fold, tear, burst, and rigidity or flexibility, to withstand such functionality or end usage.

These latter functionality requirements are what frequently necessitate the printability of the paper or board being a compromise of properties suited for printing, and characteristics associated with strength or internal structure; for, those suited best for one, usually are quite the contrary for the other.

CHEMICAL REACTIVITY

The surface pH and chemical reactivity of the stock are particularly important in lithography, which is sometimes referred to as a chemical printing process. This is because of the rather delicate physicochemical balance which makes the plate-image ink receptive and water repellent (or hydrophobic), and the nonprinting areas water-receptive (or hydrophilic). The presence of any water-soluble materials in surface or coating that are liable to destroy this equilibrium, as by chemical or plate surface reactivity, is taboo, for reason of their tendencies to cause the supposedly nonprinting areas to print—which trouble is variously known as emulsification, tinting, and greasing or scumming.

What possibly may make such troubles strictly chemical as well as colloidal or physical, is the fact that the usual dampening or fountain solutions have a pH of around 4.0, which paves the way for possible reactivity or neutralization with alkaline coatings—and may affect the image as well as the nonprinting areas.

Another source of possible indirect printing trouble through chemical reactivity of the stock is its possible action on the drier or vehicle in oxidizing inks resulting in retarding the drying of these inks. For various reasons or other, such drying inhibition is usually associated with the pH of the surface and moisture content of the stock.

Drying-oil inks ordinarily dry appreciably faster on coated than on uncoated sheets; and as the surface pH increases, the drying time tends to decrease—and a pH of less than 5.0 seems decidedly dangerous. On the other hand, as the moisture content increases, this drying time by oxidation increases; and in this case, anything over 6.0% moisture content courts trouble.

The Government's recent curtailment of the use of cobalt makes such drying troubles particularly significant at this time. There just is not enough of that best-of-all catalyst now available, for the inkmaker to give many inks the reserve cobalt drier content heretofore used as a factor of drying safety against unexpected adverse drying conditions, as might be met with in the pressrooms and with "off" lots of paper.

Possible chemical corrosion of the copper, zinc, magnesium alloy, type metal, and even nickel or chromium facing, used in letterpress or gravure plates or cylinders, may be another source of trouble under this heading—particularly, on the longer press "runs."

SURFACE ABRASIVENESS

Together with the just given chemical reactivity, the surface abrasiveness is an important factor in determining the longevity of metal plates in both letterpress and gravure printing. Excessive abrasive characteristics on paper, or in ink, are particularly apt to show up and give complaints in long runs of 100,000 impressions, or more, in fine screen printing.

Dull coating, hard texture, and coarse pigments in coating or even filler, as well as harsh, rough fiber surface, seem largely responsible for such objectionable plate wear. Furthermore, with rough and irregular surfaces that are hard or nonresilient the printer has to use excessive pressure for adequate ink coverage and, as a result, gets abnormal evidence of plate wear.

FIBER ORIENTATION (GRAIN) AND FORMATION

These characteristics are ordinarily not listed as physical properties in the same sense or category as the other nine afore-given printability factors. The probable reason is that "formation" is a structural, or internal, rather than printing surface characteristic and, in addition, is not directly measurable. However, neither is printability numerically measurable. And, since there seems no question but that degree of orientation or grain, as well as the order of formation (that is, close, open, uniform, or "wild" fiber felting), to a large extent, albeit indirectly, affects surface and printability—they are separately listed as important factors.

As example of their importance, grain and formation have considerable influence on such paper properties as: surface smoothness, uniformity and evenness of ink absorption, dimensional changes, curl, directional strength, and folding ability.

From the printer's viewpoint, grain is so important that he wishes the grain direction marked on all paper skids, and for register reasons wishes his sheets cut with the longer dimension paralleling the grain direction. For best feed, wrap around impression cylinder, and control of dimensional change or register, in sheet-fed printing, he almost invariably prints across the grain. That is with the grain at right angles to the direction that the sheet takes in its passage through the press.

Now the printer in his register work can much more readily allow and compensate for dimensional sheet change in the around-the-cylinder direction of his press. Consequently, this is the direction in which he wishes the major shrink and stretch or across-the-grain changes to take place.

You cannot blame him for being so fussy about the importance of grain in printability, and the necessity for marking the direction of same, when you stop to consider that varying moisture, or humidity, gives changes in most sheets of from two to six times greater across the grain than with it.

MOISTURE CONTENT

This is not a part of the "built-in" composition or structure of the board or sheet, but is a most important "left-in" component as far as printing properties are concerned.

Almost all of the listed printability characteristics are significantly affected by a sheet's variable moisture content. Under "dimensional stability," it has been shown how a 1% moisture change can throw a sheet completely out of register. Under "surface strength," it was intimated that it could change the pick resistance. Below "chemical reactivity," its influence on an oxidizing ink's drying rate was mentioned.

You may not know, that much over 5% moisture content gives drying trouble with high-speed heat-set publication printing, for reason of added burden on the heaters, and danger of blistering with coated stocks. On the other hand, if the moisture is too low, as below 4%, there is danger of scorching, embrittlement, and web breaks.

Most know that variable moisture content can influence "ink receptivity" and transfer by varying the porosity for penetration, and the plasticity for smoothening under impression. Five hundred years ago, the first printer, Gutenberg, moistened his papers for this reason; and the U. S. Government Printing Office still does, in the printing of some of their engravings.

All know of the influence of moisture content on the strength and folding characteristics of a sheet, and how it took many years to develop high wet-strength wraps, containers, and paper toweling.

Now the printer knows most of these things through first-hand encounters. He additionally knows that despite press grounding, eliminators and whatnot, that he has considerable trouble with static, unless his paper has at least 5 to 6% moisture content—or his relative humidity is of the order of 50%, or higher. Static, to him, spells trouble, for it usually

means jammed or double-sheet feeding, web-breaks, set-off and sticking, and frequently ink "flying" or misting.

Add this altogether and the importance of controlled and uniform moisture content in the paper or board as sent to, or used, by the printer can be realized. Unfortunately, the allowable tolerance between "trouble" and "no trouble" seems very narrow, and there is just sufficient overlap so there is no one "happy mean," or moisture content, suitable to all variables and conditions.

This is the reason seasoning and preconditioning are so necessary in most printing, and rigid air-conditioning practically a "must" in all high-quality multicolor printing plants.

All in all, 5% moisture content seems to be about a least-trouble average—though, even better, would be a preconditioning, so as to be in equilibrium with the expected humidity conditions at the time of printing.

However, somewhat contradictory to this, is the fact that most lithographers prefer a preconditioning to from 5 to 10% higher relative humidity or around $^1/_2$% higher moisture content than would balance in their pressroom atmosphere. Their theory seems to be that this gives better equilibrium in actually on-the-press conditions where the sheet's tendency to lose moisture (due to the 5 to 10% lower humidity of the atmosphere) is counterbalanced by the sheet's mechanical pick-up of moisture from the damp press blanket.

UNIFORMITY

Having established the foregoing eleven characteristics suitable to a given printing and process, the printer expects these properties to be kept uniform from sheet-to-sheet, skid-to-skid, and roll-to-roll or lot-to-lot.

Caliper and substance weight, which are admittedly very important purchasing specifications, have not been included under separate caption because it is believed that they are not quite as inherent to actual printability as other of the listed characteristics. However, they obviously do have some relation to printing properties, and must be within certain limits to make handling, binding, product thickness, mailing weights, and price considerations practical—and, of course, they likewise must be kept uniform.

By now it can be seen, that not only with every printing process—but with every job, the printer is confronted with a whole flock of variables. Having gained experience through one or several trials with a given brand of paper and board, he has most likely become cognizant of its particular printing and processing characteristics and made, or knows how to make, his particular adjustments to suit these properties. Hence, he expects any future lots or shipments to have these identical properties. If not, he may find himself in the middle of a new job when suddenly he finds some unexpected variable in the properties of the paper that costs him press time, spoilage, loss in his estimates, and assuredly loss in his disposition. After such experience with lack of uniformity, your salesman will most probably find his purchasing agent "out" or "in conference" when he makes his next contact calls.

Under "uniformity," two-sideness might be mentioned as the printer usually expects to print both felt and wire sides with equal facility and similar credible results. These two variables have been listed with the respective printability characteristics they seem to influence but have not stressed their effect. Ordinarily, the felt side is so appreciably the smoother of the two that it usually gives smoother ink lay, better finish, easier coverage, more ink mileage, and better printability, in general. The wire side usually gives faster penetration, faster though less uniform ink set, slightly faster oxidation drying, and slightly less tendency to pick.

From the above, it can be seen that any appreciable two-sideness may have significant influence on printability. Furthermore, that for this reason, the printer wishes a minimum of such nonuniformity of surface, and in anticipation of same, wants to know in advance "which side is which" by having the supplier deliver and pack the skids with "felt side up."

At the same time, the printer expects the stock to be free of external damage and internal faults and, in general, to have the following conditions in his received stock:

Sheets: To be flat and trimmed square, preseasoned and moistureproof wrapped, grain direction marked, and felt side up.

Rolls: To be tightly and evenly wound on a firm undamaged core; free from slime and scorch spots; and to have hard undamaged edges, and felt side on the outside or marked.

Both forms of stock are to be free of fuzz, lint, and cutter or slitter dust.

PRIMARY PRINTABILITY REQUISITES

I would like to review what I think constitutes printability.

Printing is a reproduction process. Its aim is to give multiple reproductions of whatever is furnished as the original.

This original or so-called "copy" may consist of art work, photographs, text, and type matter, and any combinations thereof. Now it is the printer's job to reproduce such originals, or copy in close facsimile uniformly, efficiently, and in large numbers.

To do this, he ordinarily uses any one of three major processes—which differ from each other essentially only in the design and structure of their transfer medium or plates. The transfer of ink from these various plates is the fundamental process of all these printing processes.

The efficiency and exactitude in which these respective plate designs or images are transferred (in register) onto the paper or board, and the visual similarity of such transfer to the originals, constitute, what I consider, the primary printability characteristics of the paper and ink variables involved.

There are also, what I consider, many secondary influences of printability and these, to me, seem to be those that principally determine whether or not the after-printed material will satisfactorily meet subsequent processing operations and the functionality or end usage requirements of the whole job.

Most of what I consider primary printability characteristics include, or are tied up with, paper-ink relationships such as: transfer, coverage, ink lay, finish, color, and absence of disfiguration due to set-off, smear, pick, stick, strike-through. But, of course, register, opacity, and body strength sufficient to meet the press requisites, have little or no relationship to ink. However, I consider all these sufficiently important to classify as first-order printability requisities and I have covered them in the twelve listed characteristics.

What I consider secondary influences actually have little direct relation to printability and hence do not apply to this discussion. They would, however, include such functional requirements as permanence to light, and a multitude of physical, chemical, and mechanical resistivities of ink and/or stock as liable to be needed in end usage.

The impression I would like to leave is that the less impression the printer has to use with paper and ink, the more impression he will make upon his customer, and the less trouble for us all.

Presented at a meeting of the Eastern District, Empire State Section, Glens Falls, N. Y., Feb. 15, 1951.

Plastics Conference

Technical Association of the Pulp and Paper Industry

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FIBROUS AGRICULTURAL RESIDUES CONFERENCE

Papers Presented at the 1950 Fall Meeting

The meeting at the Northern Regional Research Laboratory, Peoria, Ill., was opened on Monday morning, Nov. 13, with the customary self-introductions. S. I. Aronovsky, chairman of the meeting, then introduced R. T. Milner, director of the Northern Laboratory. Dr. Milner welcomed the group and discussed briefly the program and work of the Laboratory on subjects other than pulp and paper and described the accomplishments of the Laboratory in those fields. Dr. Milner stated that the Laboratory was happy to have these technical-industrial conferences here and he hoped that this group would come back to the Laboratory many times again.

Technical Session

The first paper of the technical session was "Protecting Large Stacks of Baled Straw with Sisalkraft," by Ralph J. Anderson, of the Sisalkraft Co., Chicago, Ill.

Protecting Large Stacks of Baled Straw with Sisalkraft

Ralph J. Anderson

SISALKRAFT has been used haphazardly for covering haystacks since we have been in business. Shrinkage and poor application hindered development of this use. In 1935 a method of treating kraft paper to resist shrinkage was developed by us. We then took up stack covering seriously.

The large stacks of baled hay out in California needed coverage. Some of them run as high as 1000 tons. Most of these stacks are built with steplike tops. These tops were changed so that they were level leaving one or two broad steps down the center. Bales were broken and a generous amount of loose hay was placed on top of the stack to allow for settling of the broken bales and also to give us the needed type of top. A well-rounded top is most essential for excellent performance. Our method of covering holds the paper firmly in position.

In 1938 the Central Fibre Products Co. tried our covers, and the results were not too good. The reason, we think, is that the stacks were 50 to 60 feet across. A practical size is 30 to 35 feet. A demonstration was put on for Archer-Daniels-Midland and they have been covering their stacks of flax straw with Sisalkraft with excellent results ever since.

The method of covering is to place 4 or 5-foot, 1-inch hexagonal poultry netting over the paper. Heavy weights are hung on each end wire. The application is simple, and the only ladder that is needed is the one used for the help to go up and down on.

Some work was done with the Weston Paper Co. Enough loose straw was not allowed for the concave settling of the stacks. The water just drained off into the low spots. The covers, however, did not blow off. If allowance had been made for this settling we feel that the results would have been much better.

Today practically all hay and straw is baled. Fifteen and one-half-foot blankets, which we laminate from two 8-foot widths, are being used extensively by farmers in many parts of the country. The farmer builds his stack to fit the covers, and the covers are applied lengthwise. These are now moving in considerable volume.

The cost of covering a 30 by 110-foot stack would be about $125. This includes the labor. One layer of our covering should last about a year. Two layers should last from 2 to 3 years. Old blankets should be saved and placed under the new stacks the following year.

Insurance companies welcome the covers. They resist sparks, and are not as inflammable as the uncovered stacks.

Thank you for the opportunity of speaking to your organization. I enjoyed visiting with some of your members and attending this interesting meeting.

H. M. BLANDIN (Central Fibre Products Co.): What is the condition of stack after 2 years using this paper?

MR. ANDERSON: Good. The paper has lasted $1^1/_2$ years in California; a year here in this part of the country. Two layers will last about 2 years.

C. G. KRANCHER (Ball Brothers Co.): You recommend building a flat top, and then crown with loose straw. How much crown is necessary for stacks 25 to 30 feet wide?

H. LYON (Weston Paper and Mfg. Co.): The crown should be 5 feet in the center.

MR. KRANCHER: The paper runs lengthwise, is that right?

MR. ANDERSON: Either way is all right but lengthwise is a better method. It will take care of some of the discrepancies in the top.

M. L. Rankin representing Taylor, Stiles and Co. of Riegelsville, N. J., then spoke on "Why Cut Straw?"

Why Cut Straw?

M. L. Rankin

BEFORE discussing the cutting of straw, I would like to tell you of various industries who are using our cutters, give you a brief history of their use in the paper and pulp industry, and tell you of the development of our new straw cutter.

In 1863, Taylor, Stiles and Co. began making high-grade knives for woodworking and paper industries. Then in 1880, 70 years ago, the first Taylor-Stiles cutting machines were made for the paper industry. Later cutters were built for other industries, namely, textile, glue, rubber, and plastic, as well as for various special applications.

In the paper industry, the fine paper mills use our cutters to cut rags for book, bond, and ledger paper. Roofing and felt paper mills cut rags, bagging, carpets, and mattresses for roofing felt, felt for linoleum, rug and table mat base materials, etc. Rope and jute paper mills cut rope, twine, and bagging, in the production of pulp for bags, file folders, and tag stock. Blotting paper mills cut cotton batting, shirt cuttings, and other rags similar to the fine paper mills. Boxboard mills cut some waste paper, string, twine, rope, and other waste. Pulp mills cut rags for rag half stock with our cutters. Cigarette paper mills cut flax straw. Over a period of years we have cut various fibers on our small and medium-sized cutters. Some of these fibers were ramie, rice, wheat, oats, and flax straws, raffia fiber, jute, and sisal. Last month we sold a machine to cut henequen fiber.

About 2 years ago, we began to consider the building of a

cutter and bale breaker for the strawboard mills. After discussing the requirements with a number of you men in the mills, and also with Drs. Aronovsky and Lathrop here at the Laboratory, I suggested that our largest cutter, the No. 34, would best lend itself to the cutting of straws for the strawboard mills. A rugged machine was required and certainly the cutter that had stood the gaff in the cutting of leather for gelatin, animal hides for glue stock, and whole rubber tires in rubber reclaiming plants, should be strong enough for cutting of your straw.

A complete new feed was designed for straw, and the cutter was built for the Hinde & Dauch Paper Co. and shipped to Trenton, Ont., Canada. While Taylor-Stiles was building the cutter, Hinde & Dauch was building a bale breaker to work with it. We have now acquired the right to build the bale breaker so that we can supply the complete unit.

Now, "Why cut straw?" There are several reasons that make cutting of the various straws highly desirable. It is a well-known fact that you can cut cheaper than you can grind. This fact our customers have proved, not only in the various branches of the paper industry, but also in many other industrial applications. It has been common practice to partly fill the digester with uncut straw, run it for awhile, and refill it several times. If the straw is cut before going to the digester, less fillings are required. By cutting straw, a considerable saving of time can be effected in filling the digester, and time can be saved in emptying the cook. Also, the beating time can be reduced. A more even cook is obtained and all of the evenly cut fibers are subjected to the chemical action for the same length of time. Less labor is required by eliminating a number of the operations that are now common practice in the industry. Stock-handling methods can be greatly improved by cutting straw. Not only can better stock systems be employed for bringing the straw to the digester, but the stock movement after cooking can be improved. Straw cutting gives uniformity in length of fiber, uniformity in cooking time, and uniformity in the sheet of paper.

By using this modern method of stock preparation, time can be saved, a more even cook is obtained, less labor is required, stock handling is simplified, and a more uniform sheet will be produced. Remember—you can *cut* cheaper than you can *grind*.

Mr. Krancher: How do you take care of straw of different moisture contents in the feeding?

Mr. Rankin: That is a pertinent question. This is a new bale breaker and we have had no experience with it. Mr. Palm can probably tell us more about that.

W. H. Palm (Hinde and Dauch Paper Co. of Canada, Ltd.): Our work on cutting straw has, up to the present time, been purely experimental. We cut both wet and dry straw and we haven't experienced any difficulty at all. As everybody knows, our setup is a mill-scale proposition; however, it has only been operated intermittently until we get all the kinks out of it. We expect that this will be accomplished in the course of the next 2 weeks now, and that we will be on continuous operation with the cutter from thence forward. There is a chain conveyor that guides the straw into the bale breaker, which has vertical dogs attached to it. This will handle any character of straw effectively, i.e., loose or bales which have just been broken open—wet or dry.

G. A. Zinkil (Central Fibre Products Co.): How about frozen straw?

Mr. Rankin: No experience yet, but it looks pretty good. We have cut frozen hides and have had no difficulty with them.

R. M. Wilkinson (Alton Box Board Co.): How do you handle broken bales?

Mr. Rankin: The bale breaker will take care of the loose straw just the same as solid bales.

Mr. Wilkinson: What is the capacity of the machine?

Mr. Rankin: Capacity is a human element—1000 pounds per minute is nominal but a lot higher, probably a ton, is possible. The trouble is that the straw can't be gotten away fast enough.

Mr. Krancher: How do you remove bale ties?

Mr. Rankin: They are cut by hand, although eventually we hope to have a wire cutter and remover.

J. J. Fiori (Stone Container Corp.): What about power consumption?

Mr. Rankin: About $117\frac{1}{2}$ total horsepower, broken down as follows:

Straw cutter	75 hp.
Feed assembly	$7\frac{1}{2}$ hp.
Bale breaker	25 hp. on main drive
Feed drive	10 hp.

E. R. Carpenter (Weston Paper and Mfg. Co.): What is the effect of wire in the cutter?

Mr. Rankin: Doesn't hurt it a bit. A lot of foreign material is found in roofing mills, and we have had no trouble in that industry. Another example is our small cutter for confidential correspondence material. It takes paper clips without any trouble. There are railroad spikes in rags of roofing mills but there has been no trouble. They nick knives but it is not serious; the blades must be sharpened at intervals, that is all.

Mr. Wilkinson: Is there need for a bale breaker? Could you run it and use a magnetic separator?

Mr. Palm: Have to break the bales as the feed is only 6 inches deep.

Mr. Rankin: Feed rolls could be set up to 26 inches but I am inclined to believe that there should be a breaker ahead of the cutter.

E. R. Carpenter: What is the cost of the unit?

Mr. Rankin: The cost of the cutter and bale breaker is $14,430.

N. S. Balfour (Alton Box Board Co.): Is the straw coming out of this cutter pretty uniform in size?

Mr. Rankin: Our cutter can be set for different lengths of cut desired. We make the cuts so many inches, depending on what you want.

R. J. Shouvlin (Bauer Brothers Co.): Is there a dust hazard?

Mr. Rankin: There is always a question of dust. In paper mills dust is usually taken care of by cyclone collectors or common hoods, but I think at Trenton there is a simple device that Palm will tell you about. There is no problem in this instance, in my opinion.

L. F. Herman (Gruendler Crusher and Pulverizer Co.): When I talk about cutting straw, it is not in rebuttal to Taylor, Stiles and Co.; we help sell a good deal of certain types of their machinery and recommend it. I have observed a lot of processes and tramp iron seems to be a big problem in all of them. I have had many discussions with the strawboard industry concerning the removal of tramp iron before processing—every other industry does this. However, as I have become better informed I can realize what a problem it is in straw processing. The Gruendler shredder, 5XE, will take anything you can put into it, wire, hatchet heads, etc., with the straw and discharge it at the rate of a ton a minute. For anyone who would like to cut straw at that rate, it will cost you about $10,000 to install a machine. This machine is an adaptation of other equipment we have manufactured for 65 years for use as a preparator in sugarcane mills, What it does is prepare the cane for the sugar mill. Cane is normally brought in with chains. These chains are hard to remove with a magnet. The machine saves the wear and tear of the mill rolls. There are about 50 in operation today.

E. C. Lathrop (Northern Regional Research Laboratory): How do you get your tramp iron out?

Mr. Herman: A tramp iron catcher is built in the machine. It is not a magnet but a pocket. We have been running straw through this unit on test. We have another machine that is a straw cutter with an automatic feed table. All you

have to do is cut the wires and let it go. I like the bale breaker because it gives a nice uniform feed. One method that was figured out is to float the straw and let the tramp iron go to the bottom. Wet straw can be cut but not in as large amounts as dry. For your information, we also have a method of pneumatically conveying straw, similar to the British.

The next paper was "Strawboard Mill Layout at Hinde and Dauch, Trenton, Ont.," by W. H. Palm, Hinde and Dauch Paper Co. of Canada, Ltd., Toronto, Ont., Canada.

Strawboard Mill Layout at Hinde and Dauch, Trenton, Ont.

W. H. Palm

This mill—situated on the east bank of the Trent River just north of the town of Trenton, which is the location where the Trent River empties into Lake Ontario—was erected in 1926 on this site due to its proximity to a good source of water and a ready labor market, plus adequate electric power. It should be pointed out that the productive rate of the plant has more than doubled that at which it originally operated, and work is progressing now on a further rearrangement of equipment, whereby the output will be increased further over the presently existing rate. The main product of the mill, at the present time, is, of course, 0.009 corrugating medium with a very small percentage of 0.009 facing material.

The general layout of the straw yard and the method of handling baled straw is conventional with that commonly employed by other mills in the industry.

Unlike most straw mills, however, a scheme has now been worked out whereby all the straw is cut in a specially designed chopper in the straw shed immediately adjacent to the mill, the machine employed having been built by Taylor, Stiles Ltd., which is a combination bale breaking and cutting device taking whole bales of straw, disintegrating them, and reducing the stems to an average length of approximately 3 to 5 inches. This unit operates 24 hours a day inasmuch as the digester arrangement provides for a staggered cycle whereby a digester is dumped every hour, there being 10 of them in operation.

The digesters are of the conventional 14-foot diameter rotary type; however, they are rotated by a spur gear arrangement attached to one of the trunnions, the opposite one being used to admit steam, instead of the usual girth gear arrangement. A line shaft has been mounted throughout the length of the building from which a belt drive is established to each digester through a clutch pulley. Straw is conveyed from the cutter located in the straw shed at ground level, to the charging floor of the digester building by a fast-running 30-inch wide inclined rubber belt which travels the full length of the digester building, and just below the roof, before returning.

At each digester a shear arrangement is provided to scoop the straw from the belt and down a chute which directs the material into the mouth of the digester being filled. There are 10 of these shear and chute arrangements mounted throughout the length of the building, one at each digester opening.

The cooking liquor presently employed is a combination of lime and soda ash, which is mixed in a ratio of 700 to 450 pounds, respectively, added to 2400 imperial gallons of water. This quantity of solution is pumped to each digester while it is being charged with 10,000 pounds of air-dry straw. It will be apparent from the foregoing that the complete cycle of each digester is 10 hours.

The cutting arrangements have only recently been put into full operation and it is interesting to note that numerous advantages have been obtained as a result of this improvement. In particular, better packing, i.e., digester is completely charged in what amounts to one fill instead of three halfway through filling period the digester is capped and given two revolutions—filling is then completed); more rapid dumping—the digester is emptied in 20 to 30 minutes (one cover only removed); and more rapid refining.

Unlike most straw mills, conveyors are not used to handle the cooked straw. The stock is dumped onto an inclined floor and sluiced with high-pressure nozzles into a shallow inclined canal from whence it is pumped into a Shartle tugboat (9000-pound capacity), where primary disintegration and washing take place. A No. 6 Shartle refiner cycles the stock from the tugboat and back into it again at the same time as disintegrating and washing are occurring. The tugboat cycle is of 1 hour duration operating on a batch basis, and it is charged and/or emptied in a period of 8 to 10 minutes.

Such paper stock as is employed and which is pulped in breaker beaters separately—passed through a riffler and then thickened—is pumped into the tugboat where the final stock mixture is prepared before passing from the beater room. The stock then passes through two No. 3 Miami jordans in series, and thence through a No. 4 Shartle refiner (used when stock conditions necessitate).

A settling system for the mixed stock is provided through which the stock passes after leaving the refiner and thence to the machine screens, which are two diaphragm-type flat screens, and then to the paper machine. Suitable chests for stock and white water are, of course, located in strategic places in the mill layout, detailed mention of which has been omitted for brevity.

The paper machine is a 124-inch Downingtown fourdrinier, trim 114½ inches. The wet-end section consists of a Voith inlet of conventional design and the fourdrinier table is of the removable type, has a Dominion shake, eight oscillating type flat boxes, and a suction couch roll. There are 66 5-inch diameter table rolls carrying the wire which is 100 feet long, 52 mesh.

The press section consists of three units, the first being a suction press and the second a plain press, both of which are straight through. The third is a plain reversing press. Arrangements are presently being made to convert the second and third presses into a dual three-roll press, the first nip of which will be suction, the second plain.

Entering the drier section, the machine has a smoothing press and 44 paper driers—which will be increased to 54 in the immediate future—set up on a two-deck arrangement with top and bottom drier felts, the whole drying unit being split in two sections. Two calender stacks and a Cameron winder are at the dry end.

The current production is between 90 and 100 tons per day, running a 32-pound per thousand square foot sheet. Maximum machine speed is 480 to 500 f.p.m., as presently constituted.

Mr. Lathrop: What is the length of the cut straw?

Mr. Palm: It depends entirely on how it comes into the cutter. The cutter can be set for varying lengths of cut from, say, 2 inches up depending on the rate of speed at which the knife is driven—alternatively, rate of speed the feed cylinder is driven. Bale breaker tends to comb the bales; arms come around, break up the straw, and comb the material. All straw doesn't go in end on. A few are almost uncut, but the average will be around 4 or 5 inches in length. The point is that you can pack the cut straw, once you get the material to the digester. You can start steaming the minute you start charging the straw. You can easily get 90 to 95 bales of straw in one fill—100-pound bales.

Mr. Wilkinson: What is the size of that rotary?

Mr. Palm: A 14-foot unit with a drive speed of 2 minutes per revolution. A large spur gear on the journal of the digester is driven by a gear reduction unit which is also hooked up with a belt to a continuous line shaft that runs the whole length of the digester building. It is clutch connected.

Mr. Aronovsky: What about washing the pulp?

Mr. Palm: Our conventional cooking formula at the mo-

ment requires 700 pounds of lime and 450 pounds of soda ash pumped in solution to the digester. We are using four conventional beater-type washers on the tugboat and operate them for about 60 minutes.

Mr. Aronovsky: Now that you are using cut straw, do you have to hose the straw down through the canal?

Mr. Palm: Using baled straw, it takes anywhere from 45 minutes to an hour and a half to empty the digester. However, when we have used cut straw, it has been possible to empty the digesters in 2 to 3 revolutions, provided final consistency, at the end of the cook, is properly adjusted.

J. E. Atchison (Economic Cooperation Administration): Have you tried sucking the straw from the cutter?

Mr. Palm: Don't think it would work unless it were dry. Wet straw would pack solid in the pipe.

Mr. Atchison: How about conveying pneumatically?

Mr. Palm: That is another problem. You have to get rid of the air which creates a dust problem. How are you going to arrange a separate discharge for each rotary? We considered putting a cutter right over the digester and have it on tracks to move up and down. This was abandoned because of the size of the unit required to do a satisfactory job.

H. J. Shatto (Fort Wayne Corrugated Paper Co.): What do you do with the dust?

Mr. Palm: At the discharge point of the cutter, there is a stack mounted, passing through the roof, in which a fan is to be mounted and which removes dust. The quantity of dust created varies with the dryness of the straw. It is believed the foregoing practice will keep dust to a minimum.

Mr. Shatto: Have you tried a water spray?

Mr. Palm: There might be a problem in the winter time. The breaker and the cutter are operated at a high rate of speed, and the discharged straw just shoots out. Straw is pretty hard to wet in a hurry.

Mr. Shatto: Have you tried a screw conveyor?

Mr. Palm: Straw is light and bulky. I don't think it would be satisfactory.

Mr. Shatto: Are your rotaries in a line? What is the length of the belt conveyor?

Mr. Palm: The total length of the belt is about 650 feet.

Mr. Shatto: How do you dump it off at each rotary?

Mr. Palm: We have a shear board.

J. S. Hart (Pulp and Paper Research Institute of Canada): Could you tell me if pulp made from cut straw requires less time in processing than that from uncut straw?

Mr. Palm: Yes, I think that is going to be the case. The thing is still a bit experimental as regards manipulation in the mill. There haven't been any sufficiently long runs.

R. W. Shew (Ball Brothers Co.): Have you tried round bales?

Mr. Palm: Haven't run into any yet.

N. H. Carpenter (Muskingum Fiber Products Co.): How fast is your machine?

Mr. Palm: Four hundred and fifty to four hundred and eighty feet per minute. Perhaps we will be able to get it up to 700 feet.

Mr. Krancher: Do you use your secondary headbox on 9-point or just on the facing material?

Mr. Palm: Just facing—9-point facing. Quite a bit of that is used in Canada instead of having a lot of intermediate caliper.

Mr. Lathrop: What is the size of the facing?

Mr. Palm: 9, 16, and 25-point sheets.

Mr. Krancher: What is basis weight?

Mr. Palm: Twenty-eight pounds for the facing type of sheet.

Mr. Herman: Getting back to the cut straw—have you tried pneumatic conveying? I know of one plant that conveys an average of 20 tons of cut alfalfa an hour 127 feet with no difficulty at all. They do have dust.

Mr. Kancher: We have had experience with pneumatic conveying, and found all our trouble was in the elbows. If you can keep moving the cut straw up an incline to the point of discharge, you can convey it. Also when straw gets wet, you have a problem. We think conveying can be done with dry straw. Over in Europe, they keep straw covered and dry.

Mr. Atchison: Most of them have sheds.

Mr. Krancher: Tops are the main problem here. When you get down into the uncovered stack, you don't have trouble. About 50% moisture in straw gives trouble.

Mr. Aronovsky: About two years ago we had the same situation at Thorold. We had to blow chopped straw through a 6-inch pipe about 12 feet high and we never ran more than 15 minutes before the elbows plugged.

Mr. Herman: At Western Electric, we propose to take all their paper boxes, all their wires, all bolts, put them through a shredder, and convey the product pneumatically 120 feet across a yard up into a boiler.

"Handling Practices for Liquid Caustic Soda" was discussed by R. A. Springer, Diamond Alkali Co., Cleveland, Ohio.

Handling Practices for Liquid Caustic Soda

R. A. Springer

Liquid caustic soda presents many engineering and operating problems to the user. These are due, primarily, to the peculiar chemical and physical properties that are inherent in the material. Approximately 3 million tons of caustic soda are produced annually, and of this total more than 80% or about $2^1/_2$ million tons are of the liquid type. Since the consumption of liquid has increased nearly twofold in the past 5 years it is increasingly important that more careful consideration be given the significant characteristics of commercial caustic soda solutions.

The word "liquid" as applied to commercial liquid caustic soda is technically a misnomer, however, it has been widely accepted by industry as denoting a concentrated water solution of caustic soda. This terminology differentiates the solution forms from the solid or anhydrous forms.

Liquid caustic soda is manufactured and shipped by all major producers in two concentrations. These are identified as 50 and 73% with the percentages representing the approximate sodium hydroxide content on a weight basis. Although they differ essentially only in their water to caustic ratios, the physical characteristics exhibited by each are quite dissimilar. Enthalpy, freezing point, and boiling point are a few of the important properties that must be carefully considered. These are different for each solution form and necessitate certain variations in methods of unloading, handling, and storage.

Relatively small quantities of liquid caustic soda are utilized by industry in the concentrated forms as received from the manufacturer. The concentrated product is diluted and because of the very nature of caustic soda solutions, the dilution problems are multifarious.

The principal means of transportation for liquid caustic soda is the tank car. A common practice is to ship the commodity in either 8000 or 10,000 gallon quantities. Recently, however, smaller amounts of 50% liquid are being transported by tank trucks for use by industries located near the producers. The recommended method for unloading liquid caustic soda from tank cars is well defined in a bulletin (Manual Sheet TC-3) published by the Manufacturing Chemists Association. This information can also be found in the alkali handbooks of all the major alkali companies. Likewise, much has been written about "safety practices" and as a consequence these important subjects have been omitted from the scope of this paper.

50% LIQUID CAUSTIC SODA

The form of liquid caustic soda most commonly used contains approximately 50% actual sodium hydroxide by weight. Commercially, this strength may vary between 48 and 51% and this establishes a freezing or solidifying point temperature range of 49 to 58°F. From an operational standpoint, it is practical to maintain solution temperatures considerably above this range. This is due to the high viscosity of 50% liquor as the temperature approaches the freezing point. A recommended minimum temperature for a solution of this strength is 85°F. At this temperature the viscosity is no more than 25 to 30 cp., and little difficulty will be experienced in transferring the caustic by standard and inexpensively equipped pumps.

In order to transfer 50% caustic by the most economical means, pipelines should be no less than 2 inches in diameter and 3-inch lines on the suction side of pumps are recommended. A consideration of the resistance to flow in a pipe for 50% liquor at 85°F. will bear this out. At a flow-rate of 100 g.p.m. the friction loss in head per 100 feet of 3-inch pipe is about 5 feet. Under the same conditions the loss in head for a 2-inch pipe is more than 35 feet. Obviously, pipe sizes smaller than 2 inches in diameter are not practicable. Regarding frictional losses in pipelines, it might be well to note that the use of two 45° fittings is preferable to one 90° elbow fitting. This is particularly important where a long suction line to a pump is involved.

Through experience, piping equipped with flanged connections has been found to be most practical. With the flanges welded to the lengths of pipe and other fittings and by the use of alkali-resistant gaskets between the flanges, leaks will be held to a minimum. Maintenance labor costs are reduced because of the comparative ease with which replacements can be made. It is also a simple matter to remove sections of this type of piping for necessary clean-outs.

To make drainage from lines complete after use, all piping should be installed with a slight slope. Avoid loops or pockets. Observance of these precautions will reduce maintenance expenditures especially by preventing frozen lines during cold weather.

To control rates of flow and for line shutoffs, the standard lubricated plug cock has been found to be most suitable and to give very economical service. Various types of valves are commonly employed, however, in caustic and caustic dilution systems the less elaborate fittings appear to be the most satisfactory. Construction details should call for a sufficient number of steam connection fittings on all piping arrangements. This makes it possible to enforce the cardinal rule of steaming out all caustic lines both before and after use.

Either the open impeller centrifugal or rotary positive displacement pump may be employed. Installation of either type of pump should include a bypass or circulating line arrangement. This reduces wear on the pump and in many cases can be used as a means for controlling rate of flow. The location of a pump in a caustic soda system should receive careful consideration. For ease of operation the suction line must be as short as possible.

Storage facilities for 50% liquid caustic soda must be of sufficient capacity to accommodate a 10,000-gallon shipment. Provision must be made for a reserve supply of caustic soda between shipments. Practically, it is suggested that the total storage space be at least double the tank car capacity or 20,000 gallons. This is a very general statement and in reality should be made dependent upon the rate of consumption. For larger users this may be insufficient whereas for small consumers the storage capacity may necessarily be smaller. Tanks may be either vertical or horizontal and preferably should be cylindrical. Choice of the proper type and size of tank is contingent on the space available and the economies of construction.

Extra heavy metal is preferred in the construction of caustic soda storage tanks. Specifications for fabrication should call for at least $^3/_8$-inch wall thickness on the body of units larger than 10,000 gallons capacity. The pipe connection for withdrawing the liquor from storage should be located a few inches above the bottom of the tank. A drain connection at the lowest point of the tank also should be included. This latter arrangement is to facilitate occasional flushing of the tank as is required from time to time.

It is desirable to place 50% liquid caustic soda storage tanks in a heated building that is maintained above 60°F. This will usually insure a storage temperature of 85°F. or higher which is optimum for handling the liquor. Tanks located out of doors must be supplied with a source of heat. A small coil or loop of 1 to $1^1/_4$-inch pipe connected to a source of low-pressure steam, 12 to 15 p.s.i., is adequate. For the average mill, automatic controls on the steam supply are not warranted. Best practice is to warm the liquor intermittently as the occasion demands. With a temperature range of 85 to 140°F. little attention is required. Avoid storage temperatures above 140°F. because caustic soda is more corrosive to steel above this point. Insulation of tanks, although desirable, is not necessarily a requirement. The most economical thickness for common types of insulation is 2 inches.

The usual materials of construction for a caustic soda system are steel and iron. Flange quality steel is preferred for tanks. Black iron, carbon steel, and cast iron are the best materials for pipes and fittings. Cast iron construction of pumps is reasonable although longer service can be expected from nickel or some of the nickel alloys. A very small amount of iron contamination will occur in systems of all-iron construction. If this is objectionable, nickel may be substituted at a great increase in cost. Nickel-clad steel, various alloys, and organic coatings are also used to eliminate corrosion of this nature.

Dilution of 50% liquid caustic soda to any desired concentration presents very few difficulties provided the method for handling the original 50% liquor is mastered. Pumps, pipelines, tanks, and other equipment previously discussed are at least adequate for lower concentrations. As a matter of fact many consumers prefer to store the diluted form and do so upon receiving a shipment from the manufacturer. Usual practice is to dilute to either 20 or 30%. This furnishes a solution that is much less corrosive and less hazardous to handle. The freezing point is considerably lowered from 54°F. for 50% liquor to 34°F. for 30%, and −15°F. for 20%. Much of the danger of the solution solidifying in pipelines and other equipment is removed. A disadvantage of handling the diluted forms is the increase in storage capacity that is required. The cost of additional tanks must be weighed against the increased operational expenses that are inherent in the 50% systems.

Dilution of 50% liquid caustic soda is a problem that confronts most industries. Table I has been prepared to present a few of the factors that must be considered when dilution of 50% caustic soda liquor is effected. The calculations for the values represented in the table were based on 1 ton of 50% liquid caustic soda (1000 pounds anhydrous weight) at a temperature of 110°F. This condition was chosen because it is an approximate average temperature at which 50% liquor will be received by the consumer. The volume of water required per ton for each dilution is listed. From a practical standpoint the dilution water temperature does not greatly affect the dilution water volume and hence these volumes were calculated at 60°F. The dilution water temperature does, however, influence the maximum temperature of the diluted solution. Provision was made to list the maximum solution temperature obtained with dilution water at various temperatures. The final volume of the diluted solution can be found in vertical column 3. This has been calculated on the basis of the average maximum dilution temperature which is sufficiently accurate from a practical standpoint.

Two points are worthy of notice. In the first place volumes are not additive functions. The total volume of diluted liquor is not the sum of the 50% liquor volume and the dilution water volume. Even though the difference is small on a per ton basis this becomes quite significant when large quantities are involved. The second feature to consider is the fact

Table I. Dilution of Commercial 50% Liquid Caustic Soda

Diluted conc. NaOH, %	*Volume of dilution water, gal.*	*Volume of solution at av. max. temp., gal.*	*Temperature of dilution water, °F.— 50 Max. temp., °F.*	*60 Max. temp., °F.*	*70 Max. temp., °F.*	*80 Max. temp., °F.*
45	27	184	130	131	133	134
40	60	214	144	146	149	151
35	103	254	145	149	152	156
30	160	308	142	146	151	155
25	240	385	131	136	141	147
20	360	500	119	125	132	139
15	560	696	100	108	116	124
10	960	1091	83	92	101	109
5	2160	2283	65	75	85	94

Note: Values based on 1 ton gross weight (1/2 ton anhydrous weight) of 50% liquid caustic soda at 110°F. (Equivalent to approximately 160 gal.)

that, in the dilution of 50% liquor, abnormally high temperatures are not encountered. The boiling points of the solutions are not approached, and hence no really hazardous conditions are established. The corrosion rate affected by the temperature as well as the concentration is reasonably favorable so that these dilutions may be made directly and no heat exchanger is required.

73% LIQUID CAUSTIC SODA

The second commercial form of liquid caustic soda for discussion is the 73% liquor. Normally, this contains 71 to 73% sodium hydroxide. At ordinary atmospheric temperatures it is a solid, for upon cooling, crystallization begins at about 145°F. Tank cars for 73% liquid caustic soda are always fully insulated. It is the usual practice for producers to load at elevated temperatures so that the caustic will be received at a temperature above 200°F.

In addition to the high temperatures required to keep 73% caustic liquor in the liquid state, a considerable quantity of heat is evolved as dilution is effected. Obviously, then, the dissipation of heat becomes one of the most important problems in the handling of this material. Table II will give some clues as to the heat characteristics of 73% liquor dilutions. The calculations for the table, as was the case for 50% dilutions, are based on 1 ton of liquor at an approximate receiving temperature of 210°F. Again the approximate volume of dilution water required for a given percentage of sodium hydroxide has been listed, and the maximum possible temperature of the resulting solution has been calculated. A practical interval of 10°F. from 50 to 80°F. was used for dilution water temperatures.

The maximum temperatures are very much higher than those experienced in the dilution of 50% liquid caustic soda. A few are near or even above the boiling point. At the higher temperatures and concentrations, the solutions are very corrosive to steel equipment and are extremely difficult to

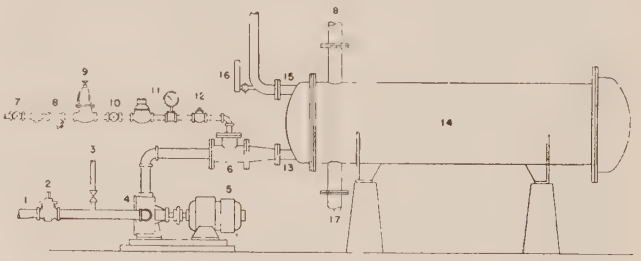

Fig. 1

	73 % caustic feed		Dilution water feed		Diluted caustic
1	Line from car	7	Shutoff valve	13	Exchanger feed line
2	Cock	8	Strainer	14	Heat exchanger
3	Steam connection	9	Pressure-reducing valve	15	Exchanger discharge line
4	Pump	10	Control valve	16	Thermometer
5	Motor	11	Meter and pressure gage	17	Cooling water inlet
6	Mixing tee	12	Check valve	18	Cooling water outlet

handle from the standpoint of safety. It is, therefore, general practice to cool the diluted solutions below 150°F. The total volumes of the various diluted solutions have been calculated on a 140°F. basis which is a good average condition. The quantity of heat that must be removed per ton gross weight of 73% caustic soda to reach 140°F. from the maximum dilution temperature is listed.

Only in the lower concentrations, 5 to 15%, are reasonable operating temperatures approached, and as can be noted the heat values become negligible or negative. Here the cooling effect of the large quantities of dilution water become evident.

The 73% liquid caustic soda is infrequently placed in storage at full strength by the consuming industries. Much heat would be required to maintain the liquid state, and upon dilution the heat must be removed. It is, therefore, a generally accepted practice to dilute the 73% liquor as it is pumped from the tank car. The concentration for storage varies according to what may be desirable; however, this is very frequently established as 50%. The caustic system is, then, treated as a 50% system from this point. Requirements for the 50% liquid caustic system have been previously discussed.

The additional equipment that is needed for a 73% caustic soda system is (1) a mixing arrangement, and (2) a means of dissipating the heat of dilution. A diagram for such an

Table II. Dilution of Commercial 73% Liquid Caustic Soda

Diluted conc. NaOH, %	*Volume of dilution water, gal.*	*Volume of solution at 140°F., gal.*	*Temperature of dilution water, °F.— 50 Max. temp., °F.*	*50 Heat to remove to 140°F., B.t.u.*	*60 Max. temp., °F.*	*60 Heat to remove to 140°F., B.t.u.*	*70 Max. temp., °F.*	*70 Heat to remove to 140°F., B.t.u.*	*80 Max. temp., °F*	*80 Heat to remove to 140°F., B.t.u.*
60	52	183	247	179,010	248	183,340	250	187,670	252	192,000
55	79	206	253	216,900	256	223,450	260	230,000	263	236,550
50	110	234	256	259,720	260	268,920	264	278,120	268	287,320
45	149	269	255	295,810	260	308,230	265	320,670	271[a]	333,110
40	198	313	249	333,450	255	349,950	261[a]	366,450	268[a]	382,950
35	260	370	237	340,270	243	361,980	249[a]	383,690	255[a]	405,400
30	344	449	219	334,640	226	363,310	233	391,980	240[a]	420,650
25	461	561	193	274,320	201	312,720	209	351,120	218	389,520
20	636	732	169	183,800	177	236,800	186	289,800	194	342,800
15	928	1022	136	−25,440	146	51,890	156	129,220	165	206,550
10	1511	1610	108	−429,400	117	−303,400	126	−177,400	135	−51,400
5	3263	3384	77	−1,758,000	86	−1,486,000	96	−1,214,000	106	−942,000

Notes: Values based on 1 ton gross weight (1460 pounds anhydrous weight) of 73% liquid caustic soda at 210°F. (Equivalent to approximately 140 gal.)
[a] Near or above the boiling point.

arrangement is shown in Fig. 1. Dilution water is metered into a mixing tee where it is combined with a definite flow of the 73% caustic soda. The solution that is formed passes through a water-cooled heat exchanger to remove the heat of dilution and thence to storage.

The pipeline from the tank car to the pump should be no less than 2 inches in diameter and preferably 3 inches in diameter. All 73% caustic soda lines should be well insulated and for added convenience steam traced. The viscosity at 210°F. is not high but cooling of the liquor near the pipe surface will appreciably increase resistance to flow. A length of more than 50 feet for the pump suction line is undesirable. The discharge line from the pump may be 2 inches in diameter. A properly designed dilution system will have a minimum piping distance between the pump and the heat exchanger.

Centrifugal pumps are used on occasion; however, a rotary, positive displacement type pump is advantageous for the dilution phase of the unloading-dilution operation. A capacity of 30 to 50 g.p.m. will permit the tank car unloading and dilution operation to be accomplished during one 8-hour shift. At this rate a reasonably economical heat exchanger can be used. The most simple dilution water feed arrangement has been shown. Proportioning and metering pumps for both the dilution water and the caustic soda have been used successfully but such apparatus increases the original capital investment.

Any standard design heat exchanger may be used. In order to determine the size unit required, certain factors such as caustic pump delivery rate, cooling water temperature, and dilution concentration must first be established. For diluting 73% liquid caustic soda to approximately 50% at a rate of 40 to 50 g.p.m. and with a maximum cooling water temperature of 70°F., an exchanger of 600 to 800 square feet of cooling surface will serve the needs of most mills. Cooling water requirements will not exceed 200 g.p.m. If the cooling water is 60°F., the volume may be reduced to under 150 g.p.m. or an exchanger of smaller dimensions may be used. Water at 80°F. would require as much as 500 g.p.m., or if preferable a unit with a larger cooling area can be substituted. Only general information on the heat exchanger can be offered for each mill may have slightly different requirements due to its own particular water balance. This is to serve only as a guide regarding what might be the exchanger requirements.

The materials of construction for both the 73% and mixing sections of the system may be black iron, steel, or cast iron. Heavy-duty piping is essential. Certain alloys and nickel will give a much longer service than iron and steel. Unless a small amount of iron contamination is undesirable the extra expense encountered for the more resistant metals is questionable. The unloading of a 73% tank car, because of the dilution that is necessary, has to be properly controlled and requires the attention of an operator. The 50% form is different in this respect for this involves only the unloading of a liquid raw material.

In using liquid caustic soda, it is the problem of each mill to decide which form is the more economical. The advantages of the 50% form are: (1) a less hazardous material to handle, (2) few heat problems, (3) less capital investment, and (4) lower operating costs. The 73% liquid caustic soda has one important advantage that can easily dictate the use of this form and that is delivered cost per unit of anhydrous caustic soda. This reduction in delivered price is achieved by paying freight charges on less water. Fifty per cent liquid caustic soda contains approximately 50% water whereas 73% contains about 27% water. The freight charge is based on the total weight of tank car contents, caustic plus water. Figure 2 is a nomograph for comparing the delivered cost of the two liquid forms of caustic soda. By way of explanation, assume that a freight rate of $0.35 per 100 pounds (including all

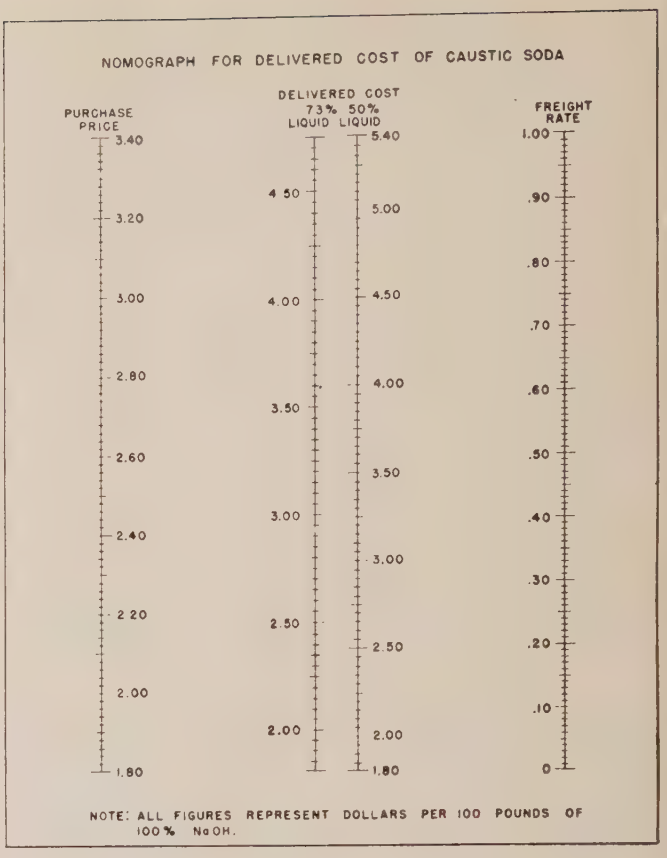

Fig. 2

taxes) is in effect at a certain consuming point. The purchase price for the caustic soda is $2.40 per hundred pounds of 100% sodium hydroxide. A straight line connecting these two points on the nomograph can be drawn. (This is not shown on the chart.) The line intercepts the vertical line entitled "50% liquid" at $3.10 and the "73% liquid" line at $2.87. This means that the delivered price of the 50% liquor is $3.10 per hundred pounds of 100% sodium hydroxide. The 73% liquor is $2.87 per hundred pounds of 100% sodium hydroxide. The cost differential is $0.37 per 100 pounds or $7.40 per ton, anhydrous basis. This margin of saving must be compared with the additional operating costs for handling the 73% liquid caustic soda.

E. R. Carpenter: We have a 42,000-gallon tank and use 22 feet of steel coil with 12-pound steam for heating. We have used cast iron piping in our tank but in one winter it wore out—lasted approximately 7 months. We tried a stainless steel coil with 35-pound steam and this lasted 1 week. With reduced pressure, it lasted 2 years.

Mr. Springer: I presume that your tank is not insulated. The application of a 2-inch standard-type insulation would permit you to use intermittent heating and thereby prolong the life of the coil. Perhaps the most economical material for the coil is black iron, even though it must be replaced each year. Stainless steel is not a satisfactory material of construction for liquid caustic soda service. Try nickel at your mill and, due to the increased coil life, this may be cheaper in the long run. For best tank and coil life it is important that you maintain a storage temperature below 140°F.

Mr. Wilkinson: How about the use of these new rubber coatings for pipes?

Mr. Springer: Currently available rubber type coatings are not satisfactory, for steam coil service, because of these materials' low decomposition temperatures. Teflon, a plastic, perhaps would do the job but present costs are prohibitive. We have done considerable work with rubber type coatings

and found them satisfactory for caustic storage tanks and pipe lines but not for heating coils.

Mr. Wilkinson: Cost of installation is one of the biggest items, so you have to balance that.

Mr. Palm: Is there any material with which you can coat?

T. Agronin (Shartle Brothers Machine Co.): Amercoat is good and better on concrete than steel.

Mr. Springer: Many organic type coatings such as Amercoat, Malacca, Neoprene, Ucilon, Tygon, and Nukemite are very satisfactory coatings for both concrete and metals provided they are properly applied. We prefer, however, the use of nickel, steel, black iron, and cast iron for materials of construction precluding the necessity for coatings. There is one point that must be stressed in regard to caustic corrosion of equipment. Avoid intermittent usage and washings if possible. The skin surface protective film is destroyed and the corrosion rate materially increased.

Mr. Agronin: With regard to pumps, I should like to stress the buying of a special pump. Don't get an off-the-shelf pump. A special stuffing box is required.

Mr. Springer: Before purchasing this item, pump manufacturers should be consulted. A special stuffing box and nickel impeller may be indicated.

Sven Fahlgren, Bird Machine Co., South Walpole, Mass., then gave a "Review of Theory in Application of the Jonsson Screen."

Review of Application of the Jonsson Screen

Sven Fahlgren

The first pulp and paper screen utilizing the technique of rapid circular vibration was the Jonsson screen. In its first form the Jonsson screen was started in a Swedish pulp mill about 15 years ago. Today, essentially the same, but with minor changes in the suspension, between 1 and 2 thousand Jonsson screens are in operation.

You all know, of course, that vibrating screens of various types have been extensively employed for years in the mining and rock products industries among others. It is, however, true, so far as we know, that this type of screen had never been applied in the pulp and paper operations until the development of the Johsson screen. Most of you present undoubtedly are already familiar with the construction and operating principles of the Jonsson screen. The screen consists of an open trough or vat divided into two or more sections. The bottom of this trough or vat contains a screen plate either perforated or slotted. The entire unit is suspended on four elastic members in a concrete, tile-lined, or stainless-clad self-contained vat. An off-balance shaft, driven through V-belts by a 3-hp. motor, imparts an intense, controlled circular, vibratory motion to the screen trough.

A patented and noteworthy feature of the Jonsson screen is the design of the trough. The special shape effects partial submersion of the screen plate and encourages quick and complete transport of rejects from feed to discharge. Because of the rapid, circular motion of the screen plate, the only contact the rejects have with the screen plate is where the plate emerges from the stock.

At this point the plate is virtually horizontal and with the circular motions of the plate the rejects are speedily moved forward to the point of discharge. The so-called dry area or beach at the discharge end represents only a small part of the total screening area. Showers, applied at strategic points in the discharge area of the screen, whisk off the few good fibers adhering to the knots or rejects. A speed-up in the discharge of the rejects is also accomplished. The loss of fibers is amazingly small—very much less than pulp and papermakers are accustomed to expect. In a number of pulp mills savings of several tons of fibers per day have been noted. Utilizing rapid, vibratory motions, as applied in the Jonsson screen, higher consistencies with less handling of water, also higher capacities per screen area and at low power consumption are obtained. A Jonsson knotter equipped with a plate with 1/4-inch perforations will easily handle from 6 to 9 tons per square foot screening area per 24 hours. These figures apply to groundwood and sulphite. Screening straw through 1/8-inch perforations will result in a capacity of slightly above 3 tons per square foot per 24 hours or approximately 50 tons per day.

The faster the removal of rejects from any screen, the cleaner the accepted stock. The rapid removal of the rejects is actually a key factor of screen performance. In the Jonsson screen there is virtually no opportunity for knots, shives, or dirt to bounce around on the screen plates and get broken up into fine particles that get through and are difficult to remove later on. To give you an idea how fast the stock is handled by the screen, about 1750 g.p.m. pass through a screening area of approximately 16 square feet with the screen operating at full capacity. At this flow at a consistency of approximately 1%, 100 tons of stock will be screened through 1/4-inch perforations in 24 hours.

The Jonsson screen was originally conceived as a knotter for groundwood and chemical wood pulp. Later on, particularly in this country, scores of screens have been put in use for the coarse screening of waste paper, deinked stock, straw, and board. The knotting of groundwood and chemical woodpulp through a vibrating screen is very efficient. High capacity at relatively high consistency and at a low power consumption makes the over-all picture very attractive.

I have previously mentioned the tons per square foot capacity; however, to give you a clearer picture of the Jonsson knotter's ability to handle wood pulp, I would like to present the following figures:

Groundwood at 2.0% consistency through 1/4-inch perforations	150 tons/day
Sulphite at 1.0 consistency through 1/4-inch perforations	80–90 tons/day
Sulphate at 1.7% consistency through 3/8-inch perforations	135–150 tons/day

Variations in consistency will affect the above capacity figures. Consistency control should, therefore, be a *must* regardless of what type of knotter is used. I will point out, however, that the Jonsson screen has the ability to accept greater consistency variations than other types of knotters, without the loss of good fibers in the rejects.

In the knotting of kraft or sulphate stock, also sulphite made according to the MgO process, the vibratory knotters can be and are used both before and after vacuum filters. It has been and still is in most cases the customary practice to knot wood pulp after it has passed over the vacuum filters. The use of rotary knotters ahead of the filters was prohibited by excess foaming. Southern kraft pulp presented a particularly acute foaming problem. Being a pioneer in this field and readily adapting itself to this particular purpose, the Jonsson screen through several successful installations has led the way to the adoption of the vibrating screen ahead of vacuum filters.

Due to the shape of the screening area with its submerged screen plate, a pool of stock is created into which a submerged inlet discharges the mixture of stock and black liquor. Open headboxes are not used. The stock is totally enclosed from the blowpit to the knotter and by streamlining the transfer area cascading and mixing with air are eliminated. A close connection to the brown stock washer is recommended although not absolutely necessary. In order to avoid foaming, a consistency of 1.5% is ideal for the knotting of soda pulp and northern kraft; 1.7 to 2.0% is recommended for southern kraft.

Brown stock, free of knots and chips, improves the washing efficiency to a marked degree. Better and more uniform

vacuum is assured and with it a substantial increase in black liquor recovery. Squeeze rolls may be used on the filter drums to obtain maximum removal of the black liquor. There is no longer the danger of damage to the wire cloth as there would be with stock full of knots and chips. The knots and uncooked chips rejected by the screen may be returned for further cooking or put through a defibrating unit.

The savings resulting from knotting ahead of brown stock washers are very substantial. Because of the possibilities of maintaining a higher vacuum more black liquor is recovered, and less chemicals needed further on to neutralize the furnish in the paper mill. Saltcake savings of 10 cents per ton of pulp have been achieved. The already widespread success of this process of knotting ahead of brown stock washers indicates that it is likely to become standard practice. A great number of Jonsson screens have been going in as bullscreens or as combined bull and knotter screens in several groundwood mills. Picture a vibratory knotter, taking up very little room and using only about 2 hp., having a capacity of 150 or more tons per 24 hours. One feature in screening groundwood through a vibratory screen is high consistency. It is possible to operate at consistencies as high as $2^1/_4\%$. The above figures vary somewhat depending on the type of vibratory screen employed equipped with a screen plate having smaller perforations, the Jonsson screen is also successfully used as a tailing screen.

The screening of Asplund defibrator stock and other semichemical stock has always presented a problem. This is due to the coarseness of the stock and its exceptionally high freeness. It is of great importance to select the proper open screening area in order to prevent matting and as a result, loss of capacity. By cutting down the open screening area, sometimes as much as 50%, we have doubled the capacity. Too much open screening area drains the water off too fast and permits the fibers to form a heavy mat that walks over with the rejects. This rapid drainage is due to the extremely free, coarse stock. The capacity of a vibratory screen, screening these types of stocks is very much lower than on the more well-known papermaking pulps. A rate of 50 tons per day through a plate with $^3/_8$-inch holes and 25 tons per day through a plate with $^5/_{16}$-inch holes can be expected. These capacities increase as the degree of refining is increased. Screens ahead of the refiners effect considerable power savings. With selective screening the accepted stock from the final line may in many cases be of sufficient quality to dispense entirely with further refining. The rejects from the primary and secondary screens would go to a refiner and then back to the primary screen.

Old paper stocks have been taking an increasingly important position as a raw material for paper manufacture. The high cost of pulp and its scarcity have naturally caused more and more interest in waste paper and deinked stocks as a source of fiber. Clean, mixed papers not always being obtainable presented a problem of expensive handsorting or efficient screening. The Jonsson screen had again proved its efficiency in doing a good job in sorting out all the undesirables as wet-strength paper, cellophane, paper clips, rubber bands, strings, and what have you. What's more, all this foreign material is free of good, useful fibers when leaving the Jonsson screen. The screen is usually installed following the rifflers and before the final fine screens. By removing all the coarse material, particularly cellophane and wet-strength papers which have a tendency to cover a portion of the screen plate in the fine screens, the latter will have an increase in capacity due to the effective screening area always being at a maximum.

A considerable improvement of quality can be effected by such a hookup because the fine screens following the Jonsson screen may be equipped with finer slots. This is because of the efficient removal of foreign matter by the vibratory screen, material which otherwise might clog the slots of the fine screens. Unsorted waste paper containing an abundance of rope fibers and strings very often causes trouble and cuts down the capacity of the Jonsson screen. The perforations get clogged and balls of rope fibers and strings are formed under the screen plate. Very often periodical brushing with a wire brush on top of the screen plate is very effective. The brushing can take place when the screen is in operation; however, provisions should be made to prevent the balls of strings from going further into the system. In more extreme cases string catchers have to be employed ahead of the Jonsson screen.

The screening of waste papers reminds us of board and filler stocks. The screen has become accepted for these types of stock. On cylinder mold machines, one screen per mold handles all the stock. Strawboard offers a very interesting example. The screening of the same used to be considered a major problem. We have now made several successful installations of vibratory screens handling straw pulp. Using $^1/_8$-inch diameter perforations a capacity of 50 tons per day at 1.0% consistency can be expected. All knuckles and cockleburrs are easily rejected and as a result increased machine production noted. One customer used to have close to 20 breaks per day. Now he operates as much as 24 hours uninterrupted and with a 7.5% increase in production. At a three-cylinder, 9-point strawboard machine, the setup usually consists of one vibratory screen per cylinder mold. For best results, the screen feeding the first cylinder should operate at a consistency of about 0.4%, the second cylinder at 0.35%, and the third cylinder at 0.25%.

All our strawboard mill installations have not been entirely successful, the cause of this being the condition of the material as fed to the screen. Whether the digestion of the straw, using lime or soda, has any influence on its physical properties, I don't know. We have found, however, that thorough washing before screening is very important. Slimy, long fibers, very often retard the screening process. Excess heat may also have a certain amount of influence on the oversized material, making the same very soft and pliable, and thus causing stringing and clogging of the screen plate. A fact is that the application of heat to ordinary uncooked straw makes the same pliable as silk.

I would like to be able to tell you more about the application of the vibratory screen for the screening of straw. Selective screening or a combination of the Jonsson and the Bird screens may be an answer to some of the problems. We have test screens available and a new laboratory where experimental screening operations can be made. A new screen, which we now are building and also have in operation, is the Bird Vibrotor screen. This screen is a vibrating, rotary screen based on experience from the Jonsson screen. It consists of a rotating and vibrating drum placed in a vat. By the use of high-frequency vibration, a high capacity at low power cost is possible. The vibrotor can also be operated at very high consistencies. Several vibrotor screens have been installed in the mills of a Dutch strawpaper and board manufacturer. At present, not being familiar with the type of paper or board manufactured, I cannot further elaborate on these installations. However, in this country, the vibrotor screen is doing an excellent job in fine screening southern kraft. Future observations and mill experiences will soon present us with enough material to cover the vibrotor screen in a separate paper. I take this opportunity to thank you very much for the attention you have given me in my attempt to bring you up to date on vibratory screening.

M. F. Knack (River Raisin Paper Co.): We have considerable foaming problems on our Jonsson screens, and I presume the answer to that would be your suggestion that the pulp requires pretty thorough washing before it goes over the screen. Probably the approach to our screens is not well designed. We come into the screen at considerable head, and we can't carry the screen as deeply submerged as you show.

Mr. Fahlgren: Why don't you try a submerged inlet? Inlet velocity should be low; 2-foot head maximum.

Mr. Knack: We recently changed from a lime cook to a caustic cook and the foaming problem was so severe we discontinued cooking with caustic. It should be easier to wash than a lime cook. The foam appeared to be made in the screen.

Mr. Fahlgren: Is the foaming taking place prior to the screen or right in the screen?

Mr. Knack: I am judging from the approach box. There is not much foam there.

Mr. Fahlgren: Rapid vibration sometimes kills rather than makes foam.

S. D. Wells (Institute of Paper Chemistry): How do you screen on a 40-mesh screen to separate nonfibrous material from fiber bundles?

Mr. Fahlgren: It is difficult to use small perforated screens. The capacity is cut down. You have to use the trial-and-error method.

Mr. Aronovsky: Will these work with 8 to 10-cut slots?

Mr. Fahlgren: The capacity is rather low. But the new vibrotor screen will do very well.

Mr. Lathrop: How big would screen size be?

Mr. Fahlgren: Forty-inch face and 40 inches in diameter. We have six in operation now and they are doing a good job. Power requirements are 1/4 hp. or less per ton.

The next paper "Disk Mill Refining of Strawboard Pulps" was given by L. E. Eberhardt of the Bauer Bros. Co., Springfield, Ohio.

Disk Mill Refining of Strawboard Pulps

L. E. Eberhardt

This is far from a complete report. Briefly we have worked on several different lines. Part of the work was done in cooperation with the Northern Regional Research Laboratory here in Peoria. They prepared several hundred pounds of Hydrapulper-cooked straw which was forwarded to our laboratory in Springfield. The purpose of this particular phase of our work was to determine the effects of both the double and single-disk types of refiners on mechano-chemical straw pulp.

In doing this we used three different types of machines: two single-disks and one double-disk, and the work was done in both on one and two-pass operations. We used all the combinations that we could work out with the machines in our laboratory.

We ran the following tests: single-disk refiner, double-disk refiner, single-disk with a second pass through a single-disk, single-disk with a second pass through a double-disk, double-disk followed by a single-disk, and double-disk followed by a double-disk. Some people may question why two-pass operation is considered. We did some previous work with Ball Brothers last Spring and in that test work we found that it was very practical to use a vacuum filter for washing. With the vacuum filters, it is essential that the freeness reduction before the vacuum washer be held to a minimum. This can be accomplished by one pass through a disk refiner. If you slow the stock down too much you cannot get proper drainage. The washed stock is then hydrated by another pass through a disk refiner.

We have made some preliminary evaluations on the refined pulps. The complete evaluation is in progress at the Northern Laboratory, and the results will be published in a joint paper by the Northern Laboratory and the Bauer Brothers Laboratory.

Following a suggestion from a paper read 2 years ago we did some preliminary work on another process which we thought looked interesting. Mr. Atchison, on several occasions, discussed rather completely the Celdecor process used in European countries, and we tried a modification of this idea. Bright whole wheat straw was wilted with caustic soda solution. Then the wilted straw was introduced into a single-disk machine with heavy devil-tooth plates to give it a very light chop or cut in order to thoroughly impregnate the chopped straw with caustic soda and also to get the material to handle easily. The straw was thus reduced to lengths of about 1 to 1 1/2 inches.

The cut, impregnated straw was steamed at 212°F. in a laboratory rotary digester for 1 hour. The rough yield calculations varied with the percentage of caustic soda used and the best results obtained so far were with 6% caustic soda with yields of around 80%. The washed pulp yields dropped to 73 to 75%. After the material was removed from the digester, we ran it through refiners in various combinations. The work is still very preliminary, but the results were satisfactory and the pulp compared well with conventional pulps received from strawboard mills.

Mr. Wilkinson: On the straw you had in the Laboratory, naturally it was screened and all cleaned up—what about straws with baling wire, bolts, axheads, etc.? What will it do to the plates?

Mr. Eberhardt: Frankly, it depends a whole lot on the size. If the wire is short, it goes through easily but anything can happen. Tramp iron is certainly a problem in disk refining. However, if the baling wire is chopped up ahead of the disk machine, some of it will go through but there are accidents.

C. W. Converse (Sprout, Waldron & Co., Inc.): As another manufacturer of refiners, I should like to add to that. Tramp iron is one of our biggest problems. The obvious solution is taking tramp iron out before it gets to the refiner, and magnetic equipment can eliminate all the material. You can use various types such as magnetic pulleys, permanent magnets. You can even remove tramp iron in the pipe lines.

Mr. Eberhardt: Relatively the same type of machine is used in the powder metallurgy industry, but the mixture of pulp and metal does not work so well in the disk machine. It doesn't do jordans and beaters any good either. Actually, this is a very difficult problem. As Mr. Converse pointed out, there are various means of removing tramp iron and we also feel that there will be changes in the processing of the material prior to the disk refiner that will eliminate the problem to a certain extent. At the present time, bale ties that have not been removed from digester pit stock and that get tangled in straw are very difficult to remove.

Mr. Aronovsky: Another way is to prechop the straw which would then not have a tendency to entangle tramp iron.

Mr. Wilkinson: I won't say we know about magnets, but we have one of the largest magnets and we still don't remove the iron. Straw wraps around the iron and the flow carries it along.

Mr. Agronin: With regard to use of magnets, one southern mill found that it was possible to remove the foreign material in kraft lines. The trick was to keep the magnetic field down to not more than 5 inches deep with an electric magnet. If the field was more than 5 inches, the foreign material would go through.

Mr. Lathrop: I don't believe this is on the market yet, but a development engineer of International Harvester, who visited us the other day, said they are developing a cord with very high tensile strength as binding twine, using fiber glass and plastic. That might provide the answer if it comes into the market. I think this material would be strong enough to give a good type of bale. It would probably break up in the rotary. With regard to cost, they could get it down to about 10 cents per pound. It isn't that far down now, but they have made some very good reductions in cost already.

Mr. Aronovsky: We tried some tests on it in our Laboratory. Mr. Nelson can tell about the solubility tests on this cord. Our idea was to dissolve it in the rotary.

G. H. Nelson (Northern Regional Research Laboratory): We tried dissolving the cord in dilute caustic but it was not completely soluble; it would dissolve in strong caustic solution but we didn't try it under pressure.

Mr. Hart: Is this cooked straw long, or is it cut in the Hydrapulper?

Mr. Aronovsky: It comes out cut from the Hydrapulper.

Mr. Hart: Can the refiner take long straw?

Mr. Eberhardt: It depends on how long it is. You do run into some feeding difficulties with long straw.

Mr. Krancher: The double-disk won't take long straw.

Mr. Eberhardt: With the single-disk machine you have very little feeding problems with long straw.

Mr. Aronovsky: That is the reason for the two-pass operations.

Mr. Wells: There is one type machine that is not bothered by tramp iron and that is a rod mill. It will handle tramp iron. The refined stock can then be diluted and riffled to eliminate the metal and other heavy impurities.

L. F. Herman, Gruendler Crusher and Pulverizer Co., St. Louis, Mo., then gave "Results with Turbo Pulp Refining."

Results with Turbo Pulp Refining

L. F. Herman

In order that the terminology of this type or method of equipment is thoroughly comprehended, I would like to point out that the term "turbo" pulp refining is that method of refining wherein a rotor containing one or more elements is actuated in such a manner as to produce a turbine effect. The prime purpose of this type of machinery is, first, to create centrifugal force and effect. The specific phenomenon for this purpose attached to centrifugal action insofar as the mechanics are concerned, is to take the fullest possible advantage of the effect and efficiency of centripetal and centrifugal work advantages. The axis of rotation is fixed in a horizontal plane while the rotor is so constructed as to have forces acting in three planes.

In utilizing such a mechanism, the obvious factor of impact had to be taken into the deepest consideration. In order that the fiber particles or bundles or individual fibers be not mashed, cut, or destroyed, it was necessary to design into the rotor an axis or center of percussion. The axle reaction of the rotating shaft, if completely fixed, would create direct impact. Therefore it became necessary to reverse the senses of resultant force and create a couple. This couple was created by the installation of a secondary axis some distance from the primary axis. This then resulted in the mechanical picture of having a rotor, outboard of which was created another axis or shaft upon which were hung flat plates fixed to the outboard axis. This created the equivalent of a pendulum on a turbine-type rotor.

The rotor then began to assume the configuration of what has been known for years in the reduction industries, namely, a swing hammermill. This, however, did not suffice as such a machine is intended primarily for direct impact. What was desirous to obtain was angular impact in order to achieve the phenomenon of something similar to combing or carding.

It is quite well known that water or liquid, being incompressible, acts as an opposing force to any impact blow. Therefore, it was decided to install a water reservoir against which the revolving turbine blades could operate. Considerable work in trial and error was done to achieve all of the structure, as well as the internal work surface of the unit. The results, which I shall quote, not only show that there is no fiber damage but also bear out the fact that another important physical effect takes place, and that is one of hydraulic action.

The hydraulic forces surrounding each fiber, fiber bundle, or fiber group act as a cushion and a direct medium which retards the cutting action of the swinging members attached to the rotor. This allows a tremendous centrifugal energy force to be exerted without lacerating or damaging the fiber structure in any way.

Microphotographs show that the fiber lengths are very desirable and that there is no damage to the fibers after passing through the turbo refiner.

The following data are a part of that which we are submitting for your information and study. The following test on a hard-cooked caustic soda straw pulp showed an actual demand of 231 hp., based on 50 tons of pulp, dry basis, in 24 hours.

One Hour NaOH Hydrapulper Cooked Straw

	Freeness, ml. (Schopper-Riegler)	*Burst strength, points*	*Ring crush (Riehle) 2-in. strip, lb.*
1 pass	620	51	26
2 passes	610	54	28
5 min. recirculate	620	57	29

The following Bauer-McNett fiber classification was made on a test run of oak in comparison with another type of refiner which we shall call refiner X:

Fiber Classification

Screen size	*Oak pulp mixture from three Chemipulpers*	
	Turbo refiner 1/8 inch, %	*Refiner X, %*
No. 8	1.1	2.3
No. 14	11.5	8.0
No. 28	21.1	15.7
No. 100	49.6	42.4
Through No. 100	16.7	31.6
Coarseness modulus	114.8	114.9

Bauer-McNett classifier run for 15 minutes using 10-gram moisture-free samples. Tests run in duplicate and results averaged.
Coarseness modulus is an arbitrary value based on the sum of fractions muliplied by the following factors:
Per cent on no. 8 mesh × 4;
Per cent on no. 14 mesh × 2;
Per cent on others and that through no. 100 × 1.

It is quite apparent from both of these particular test result figures that turbo refining creates directly a most desirable cumulation of effects. One of the more noticeable features that we experienced was the fact that the stock hydrates to a high degree and yet, as evidenced by the freeness factors, is in a condition applicable to running board machines at higher speeds.

The conclusions resulting from the fiber classification on the oak pulp alone, definitely show a minimum of both extreme coarse shive, namely on the 8-mesh screen and also a minimum of fines, material passing a no. 100 screen.

A prime feature of the turbo refiner is that we have a controllable discharge dam. This machine operates through a constant water reservoir. One of the specific advantages of the turbo is you can introduce hot or cold water or liquor in order to get the discharge consistency you desire. Speed of the rotor is predetermined. The screen process discharge through which the pulp passes controls degree of refining. Coarser residual material is reworked to screen size. The water level is varied by experience to get desired product.

J. E. Sapp (Gaylord Container Corp.): How does this differ from an ordinary hammermill?

Mr. Herman: A hammermill works entirely on the principle of direct impact. In a hammermill you are reducing in solid form by causing the material to be impacted against itself. Disintegration is done by impact of material on material or hammer on anvil. There is no touching of the mechanism in this machine. Liquid is incompressible. Turbulence of high speed does the work. In a hammermill you can hit every piece. Here you depend on hydraulic forces and centrifugal action with turbulence.

Mr. Sapp: Is direct impact bad?

Mr. Herman: It plays havoc with the fiber.

Mr. Palm: What is the size of opening in your screen?

Mr. Herman: Screens and louver plates will change dependent on results desired or whether a primary or secondary stage is involved.

Mr. Sapp: You wouldn't be able to lower the freeness by any appreciable amount?

Mr. Herman: I would say you could get a lower freeness by passing the materials through more rapidly. You don't get a 620 freeness if you pass it through a more open configuration.

Mr. Aronovsky: According to your figures, you get the same freeness with one or two passes through the machine.

Mr. Herman: Not always; usually longer processing produces lower freeness.

The final paper in this session, "A New Method of Cleaning Straw Pulp," was given by Carl G. Krancher, Ball Brothers Co., Noblesville, Ind.

A New Method of Cleaning Straw Pulp

Carl G. Krancher

The method of cleaning indicated in the title involves the application of the Hydraclone, manufactured by Shartle Brothers Co., to handle the furnish just prior to its entrance into the cylinder vat of a straw paper cylinder machine.

The Hydraclone is a centrifugal velocity type separator, designed for the purpose of eliminating objectionable foreign material from any type of pulp at low consistency.

Stock enters a tapered inlet at the top, thence it moves downward through a stationary spiral encased in a steel cylinder, 10 inches in diameter, which increases stock speed and imparts a swirling motion to the stock. Centrifugal action forces the heavier particles of foreign material, having a specific gravity greater than water, to the outside of the casing. The cleaned stock, however, follows the spiral or guided helix and enters an inner casing where it is conveyed out of the Hydraclone through a 90° discharge elbow.

The foreign material drops by gravity into a bottom compartment where it is conveyed by a motor-driven screw. These rejects are forced through a weighted door, and drop into a wheelbarrow or box for disposal.

In our installation, the Hydraclone was installed on the backside of our 110-inch trim, one-cylinder straw paper machine, producing about 50 tons paper per day. Stock at 2.5% consistency was taken from a consistency regulator, run through a small refiner, and thence into a box where it was blended with about 1000 g.p.m. of returned water pumped from the cylinder vat.

From the box the stock at about 0.8% consistency was pumped through the Hydraclone and discharged into another mixing box from where it flowed by gravity onto the cylinder in the usual manner.

Rejects were collected during a week's run, and found to weigh 310 pounds for 264 tons of paper (6 days) = 1.22 pounds per ton. Another run of 4 days resulted in 240 pounds rejects for 190 tons paper = 1.25 pounds per ton. Analysis of these rejects was found to be as follows:

Retained on 10 mesh	61.0%	mainly chips and heavy metal particles
Retained on 20 mesh	11.8%	metal and grit
Retained on 40 mesh	11.8%	fine metal and grit
Retained on 60 mesh	8.7%	grit
Retained on 80 mesh	0.8%	grit
Retained on 100 mesh	1.4%	grit
Past 100 mesh	3.1%	
Fiber	1.4%	
	100.0%	

Making a comparison of pounds of rejects to pounds of paper made does not give a fair picture. The true picture is one of cleaner paper and fewer breaks in the press section. We also expect greater felt life and fewer grindings of rubber press rolls.

Our furnish consists of about 35% waste paper, mainly old corrugated, and 65% straw pulp. No screening or riffling is given either stock although there is a junk remover and rag catcher on the breaker beater where the waste paper is beaten up. Also magnets are installed in feed trough ahead of jordans.

We installed the Hydraclone on the paper machine on a trial basis purely because it was the only point at which the consistency was proper for the operation of the machine. For best operation of the Hydraclone the consistency should be not over 1.0%.

An ideal installation would be to install Hydraclones in the beater room, one on straw pulp, and one on waste paper. This would have meant installing a stock thickener on each system in our case; we made ours on the paper machine to reduce the necessary equipment and minimize installation expense.

A timer, placed on the screw motor since installation, was set to operate the screw only 1 minute in 15 minutes, saving wear on this part of the equipment. It is now set for $6^1/_2$ minutes out of every 15, since there seemed to be more paper breaks with the closer spaced setting.

The advantages obtained with the Hydraclone are: (1) cleaner sheet of paper; (2) fewer breaks at wet end and between second press and driers; and (3) simpler operation than with other types of equipment.

In summary, the installation has helped a great deal. It did not remove the nodes in the straw pulp and heavy particles of paper as we had hoped; however, it is a very worth-while installation. At its limit of capacity—50 tons per day—it gives a cleaner paper and fewer breaks on the wet end of the machine.

Mr. Knack: What inlet pressure do you have to have?

Mr. Krancher: Sixteen to eighteen pounds. We are running about 16 pounds at intake and 2 pounds at discharge. We have gages at both points and are getting 1000 g.p.m. through the unit. Sometimes we have difficulty in trying to run all the water through it and at other times we cannot get enough water so we have a bypass connection. We run all the straw pulp through it and all water up to 1000 gallons. This works out at 0.8% consistency.

Mr. Agronin: Relating our experience on this machine may be of interest. There is a definite demand for a cleaner sheet of paper and this is a very simple and easy way to clean up the sheet.

Mr. Fiori: We were the first ones to experiment with Hydraclones. We had an old-time settling trough which was full after 3 days' operation—using 100 tons per day of waste paper. After ironing out with Shartle Brothers on experimental equipment and after 13 days of operation, we did not find more than 2 quarts of material in our settling trough. This is quite a record for a piece of equipment of that kind. We have found that by taking out all metals over a period of a

year our jordan life has increased, and we are getting better tests on our board. We shut down every 13 days for cleaning. Sand is practically completely eliminated. We have two or three types of cleaning in other plants. This machine operates itself once it is started.

Mr. Shew: The first week we ran this Hydraclone I would say that practically 90% of our breaks on this machine were eliminated. They occur at our smoothing rolls where the metal has been carried over into the sheet and the rolls are set so close together that 9 out of 10 pieces of material will not go through, and back up, causing the sheet to break. The first week we ran this Hydraclone, we ran screw rejects continuously. I can truthfully say that we eliminated 90% of the breaks. Last week we started out operating the reject screw at the rate of 1 minute out of every 15, figuring that the amount of rejects that we had for the previous week—210 pounds—would not warrant the continual operation of this screw. It ran swell for the first 18 hours. Breaks began to occur on the smoothing roll the first night until the tour boss blew the dump out. That eliminated the breaks until the next night. I set the dump up to 3 minutes and this helped. It is now set at $6^1/_2$ minutes out of 15 and it will run at that rate for 24 to 30 hours before we have too much apparent carryover.

Another thing, in the first week we did not have too good a mixture before the stock reached the Hydraclone. We changed that the second week we had the machine in operation; we obtained complete, thorough mixing of our straw and water entering into the Hydraclone and obtained much better results. I don't think I have seen anything in the past year in my opinion which has been as much help to the papermakers as this Hydraclone.

Mr. Wilkinson: What horsepower is required for operation?

Mr. Shew: About $26^1/_2$.

Mr. Atchison: Has anyone used 10-inch vortraps?

Mr. Knack: We use them on board machines and they are very satisfactory.

Mr. Shew: I might add that we can take out the very small amount of fiber left in rejects. I think 90% of the straw in our rejects is nodes. Finished sheets do not have bunches of node as we have had in the past.

Mr. Aronovsky: How about cockleburrs?

Mr. Shew: Never bothered us at all.

Mr. Agronin: Another thing to add about cleanliness. On checking samples, I was amazed at the fineness of the sand. The machine is designed to operate at 0.8% consistency. In the Fiori mill it never got down to that. The effect of consistency on efficiency of removal is very interesting. We get almost 85 to 93% total grit removal up to 0.9% and then start dropping off to 65% removal at 1.5% consistency.

Concerning costs to take out dirt, when we started with this problem paper mills thought they could not afford to put power into cleaning up straw paper. This line of thinking was wrong. You get a secondary return: a cleaner sheet and a saving in felt and roll life. Dirt gets you into trouble. We found that we could take out about 92 to 93% through a 60-mesh screen; beyond that you require more power but remove finer grit. The Hydraclone while relatively new was started about 5 years ago. The designs were developed about 2 years ago when we started laboratory experiments. One year was spent in the laboratory and then it was put into Fiori's plant. The finished machine takes 1000 g.p.m. We have another one for 500 g.p.m. and expect to have a third one at 250 gallons.

Mr. Knack: How much wear at end of year on the discharge screw of the machine at Fiori's mill?

Mr. Agronin: We had a lot of trouble. In one week we wore out the first screw. We are now making the screw out of chrome steel and when last checked at the end of 4 weeks' run there was no appreciable wear. We have a screw made out of new material which we have developed, called "Sharloy," and it is hardened all the way through to 540 Brinell. This eliminates wear on the screw. Another advantage of this machine against competitive machines is that there is very little loss of water. It uses 3 g.p.m., and the rejects come out at 45 to 50% dry.

Mr. Aronovsky: Is there wear of the casing?

Mr. Agronin: None.

Mr. Fiori: The same one is still there. No wear at all except the screw.

W. J. Delmhorst (Delmhorst Instrument Co.): Maybe you could use a rubber screw.

Mr. Agronin: No, with sand, glass, metal, steel, it does not last. With Sharloy you get the same relative wear as obtained with Hydrapulper rotors. We tried 12 different metals and found hardened chrome steel held up best. Meanwhile, using Sharloy in the Hydrapulpers gave $2^1/_2$ times the life of regular chrome steel.

Mr. Wilkinson: Is this a forerunner of machine called the elutriator?

Mr. Agronin: No. The elutriator is set at 10× gravity and this is 120× gravity.

Mr. Wilkinson: What will vibration do to this machine? It broke up the action in the elutriator.

Mr. Agronin: No effect in the Hydraclone.

Mr. Atchison: What pressure do you need to get 100× gravity?

Mr. Agronin: The inlet pressure is about 21 pounds = 100× gravity and 26 pounds = 120× gravity. This depends on diameter of the tube.

The technical session was closed with a brief round-table discussion on "Straw Procurement."

Straw Procurement

Mr. Aronovsky: To begin the discussion, we will start with the straw buyers.

Mr. Lyon: Concerning the straw situation, we all have had difficulty in getting straw and it is costing more money this year. Our mill has had 25% of normal straw due to thin crop, weeds, etc. We have had to branch out and get straw from greater distances.

Mr. Aronovsky: Let us hear from Mr. Dunlop on the northern Ohio area.

G. A. Dunlop (Ohio Straw Co.): The crop this year was light due mostly to weeds. According to the state department of agriculture, about 20% of the wheat was abandoned in Ohio this year. The weeds grew faster than the wheat. We have had the same trouble as everyone else in obtaining straw. We anticipate trouble next year according to figures available. A lot of the acreage that is intended for wheat will not be planted because of the late corn crop. There are hundreds of acres of corn still in the field, and it is too late to plant wheat.

V. E. Bush (Hinde and Dauch Paper Co.): Only one comment to make, I believe that in the future straw buying policies of the different companies should be on a higher level than in the past.

Mr. Aronovsky: Two years ago the strawboard industry went all out on an educational program. The response to this was very gratifying to the industry. No such program was conducted last year or this year. It seems to me, if I remember correctly, that when we started we thought the only way to get straw buying on a satisfactory basis was through a continuous educational program. After all, farmers will probably forget from year to year. Whether this would help the present situation we have no way of knowing, but continuance of this program might help a great deal.

Mr. Shatto: Two of our big troubles are that last year we did not buy enough straw, and the elements got us this year.

Mr. Lathrop: The mills think there is going to be a

shortage next year. I think what Mr. Aronovsky had to say about the educational program is probably your strongest bet. The wood pulp people have an educational program to get the farmers' wood. After all, I think most of us realize that the program must be repeated to be successful. I agree with Mr. Aronovsky that if there is liable to be a shortage next year, it would be desirable to start early with an educational program in your community. It will do you good and help straw procurement and prices.

MR. WILKINSON: We are still using the radio, leaflets, and contact by mail. We have found out that farmers do not like to sit in the mill yard because they have other things to do. If they have been in the yard for more than an hour, we find out why and if it is our fault, we apologize. We have increased handling capacity to eliminate need for anyone staying more than an hour unless they desire to do so.

MR. ARONOVSKY: You have a very good point. We have to have satisfied farmers. Mr. Milner just told me that there will be no crop control next year. Will that affect the situation? Is there any indication of an increased crop next year or does anyone know of increased wheat planting?

MR. LYON: We will have more wheat planted next year in southern Indiana.

MR. LATHROP: In southern Illinois too?

MR. LYON: Yes. Beans were harvested early, and the corn is mostly out.

MR. WILKINSON: What do you think of the cycle of beans 1 year and wheat next?

MR. MILNER: All new variety beans are coming out earlier. The farmers have expressed themselves, and they want 10-day earlier beans than standard varieties.

Annual Banquet

The group attending the meeting then adjourned to the Pabst Brewing Co., Peoria Heights, Ill., where a tour of the plant was made, followed by a social hour and the annual banquet. After the dinner, R. G. Macdonald, National Secretary of TAPPI, spoke on the activities of TAPPI and described the various Fall meetings held in 1950. R. T. Milner then introduced the speaker of the evening, L. W. Hesse, director of community relations of Keystone Steel and Wire Co., Bartonville, Ill., who addressed the group on "What Is Today's Steel Situation?"

What Is Today's Steel Situation

L. W. Hesse

Two months ago when Dr. Aronovsky asked me to talk before your group, there was considerable interest in the steel situation across the country. Action in Korea was critical, General MacArthur's men were set back in a corner of the peninsula, needing armaments and man power. The building boom was at its height; in all corners of our land people were buying and prices were skyrocketing.

That seemed an excellent time to look at the steel situation for steel was needed for Korea, for armaments, for machine tools, for ships, for vehicles, for planes, and for containers. The construction industry was crying for steel, for nails, for bolts, for reinforcing concrete, for trusses and girders. And industry was making unprecedented call for steel to expand their plants, to produce more automobiles and appliances and tools, to build freight cars, to dig oil wells and lay pipe line, to produce crops on our farms.

The over-all picture has changed considerably in these past 2 months, yet steel continues to be front-page news. There's considerable pro and con discussion regarding the industry's adequacy to meet present and future needs.

I'd like to share some information with you about what is happening in this world of steel. The information I'll pass on to you will not contain any original thinking or ideas. It will be factual, it will be from records of the American Iron & Steel Institute and trade publications in the steel industry.

To preface my remarks, let me quote from the Sept. 11 issue of *Steel* magazine. "Latest Munitions Board estimate of total steel required for military purposes in the 12 months starting Nov. 1 is 4.1 million tons of finished products, or about double the tonnage consumed by the military in the fiscal year ended last June 30."

Commenting on this total, the editors of *Steel* said it would be "practically painless to superimpose on civilian requirements without discomfort except for sheets, strip, and certain sizes of seam less tubing." In these past two months, the Munitions Board has not released any later estimate of steel requirements for military purposes, although it seems probable that with a potential armed force of 3 million men there will be greater requirements.

How much steel might our war effort need?

In 1943 World War II took a maximum tonnage of steel for direct war uses. That was 22.8 million tons—38% of the total produced. In 1944, the peak year of World War II steel production, 19.9 million tons went into direct war uses. That was 32.9% of the nation's output. Direct war uses include ordnance, projectiles, tanks, aircraft, all shipbuilding cantonments, and construction of defense plants.

In 52 months of World War II, from Jan., 1941, through April, 1945, the makers of ordnance, projectiles, and tanks received 9% of total steel output. Five per cent went for building defense plants, cantonments, etc.; 13% went to shipbuilding. During these 52 months, 24% of the nation's over-all steel output went to direct war uses. That was $63^1/_2$ million tons of steel.

Gentlemen, do you know how much steel this nation is producing today? The annual capacity as of this date of the steel industry is 100,563,500 tons of steel. A press release dated Oct. 30 by the American Iron & Steel Institute says, "For the seventh consecutive week steelmaking furnaces will be operated at an average of more than 100% capacity. The operating rate of the steel industry will be 102.4% of capacity; a total of 1,975,000 tons of ingots and steel for castings is scheduled to be made this week. In the corresponding week 1 year ago, the production totaled 162,000 tons—the steel strike was on at that time, as you know."

The current expansion program within the steel industry sees a total production capacity by the end of 1952 of 109,963,000 tons of steel per year.

Compare this with the industry's capacity at the end of the war. It was 90,000,000 tons.

So, in the 5 years between fighting the Japanese and the North Koreans, the United States steel industry added 10 million tons of steel capacity. Converting that into finished products should take care of the 4.1 million tons that the Munitions Board says will be needed for direct war uses in this year.

At 100 million tons, annual steelmaking capacity in the United States exceeds by 9% the total steel produced by all other countries of the world in 1949, including estimates for Russia and Communist dominated countries. Output from American furnaces operated at capacity for 1 year would, therefore, exceed by toward 8 million tons, last year's output for all other countries of the world including Russia and its satellites.

Since 1940, the United States has improved its position in world steel production. In 1948 it turned out 52.1% of the world's output, compared with 43% in 1940. In these 10 years the United States has increased its superiority in steel production over the Soviet and its satellites from less than 2 to 1 in 1940 to more than 3 to 1 in 1950, based on an annual operating rate of 94,000,000 tons during the first 6 months of this year.

Within the last $10^1/_2$ years alone, steel companies of the United States have built more capacity than the 1949 output

of Great Britain, the third largest steel producer in the world, and almost as much as the entire 1949 output in Russia, the second largest producer of steel in the world.

Our total steel capacity of 100 million tons compares with Great Britain's 1949 output of 17 million tons, of Russia's output (as estimated by *Iron Age*) of 23½ million tons. At our present rate of production, the United States steel furnaces in 18 weeks can match Russia's annual steel output.

Tomorrow afternoon you gentlemen who stay over will have an opportunity to see one of the nation's steel mills in action. That's the Keystone plant here in Bartonville. Now many of you, possibly, have never heard of Keystone, yet we rank about 14th in the nation's steel production. In the output of steel wire, our capacity is 15% of the nation's 1949 output. In nails and staples, our capacity is 8% of the nation's 1949 production. In barbed wire, our capacity is 23% of U. S. production in 1949, and in woven wire fence Keystone's capacity is 65% of what was produced in this country last year.

Now we didn't produce at capacity in all these departments. Actually, Keystone's steel production was above its rated capacity. This steel was converted into wire and wire products and more fence than we ever sold before. Forty per cent of Keystone's output finds its way into the agricultural market in the form of fence, netting, barbed wire, and staples; 40% goes to industry as wire which can be converted into wire rope, springs, tire beads, coat hangers, bolts, nuts, and thousands of different items; and 29% into the construction field as welded wire fabric, reinforcing for stucco and plaster, and nails.

We're looking forward to your visit to Keystone because there you will see an example of what the steel producers across the nation are doing to maintain the country's strong position to cope with any national emergency. The steel industry believes it is prepared to take care of the country's war and defense needs and will exert every effort to do that job. In so doing, though, it wants to continue to fill civilian steel requirements insofar as possible.

In the last 5 years, the American steel industry has spent over 1½ billion dollars adding 8 million tons of steel capacity. Another 9½ million tons is scheduled to be added to this capacity by the end of 1952. With the Munitions Board estimating the nation's requirements for 4.1 million tons of steel during the next year, civilian requirements for steel need not be restricted, providing consumers buy only their immediate needs.

Gentlemen, that is a big provision—"if" consumers buy only their immediate needs. But "if" consumers will do this, and barring unforeseen military requirements, don't you think that the steel industry will be able to take care of both war and civilian requirements?

Meeting of Fibrous Agricultural Residues Committee

MR. ARONOVSKY: The report on the activities of last year will not take too long. We want to take some time to talk about future work and about our committee structure. I think we shall take up the activities of the committee first.

As you know, we had a meeting of our committee at the Annual Meeting of TAPPI last February. I think there were 5 or 6 persons present. Monday afternoon at the National TAPPI meeting was considered the best free time, but apparently our committee activities didn't counterattract the activity in the hall.

Procurement, Storage and Preservation Subcommittee

MR. ARONOVSKY: Some work on preservation was continued during the year. Mr. Blandin will give us a report on the activities of the Procurement, Storage, and Preservation Subcommittee.

MR. BLANDIN: Charlie White has been around to the mills and he knows more about straw preservation work than I do. But there is one thing I might report. We made some experimental cooks on 2-year-old straw treated with borax. We ran cooks on the top four tiers; we obtained a normal yield on the top tier and about 20% less yield on the other three, so it looks to me like the first four tiers should be treated. That is just a thought; someone else may have had similar experience.

C. W. WHITE (Pacific Coast Borax Co., Division of Borax Consolidated Ltd.): I think that generally the work on borax treatment is progressing well. Not quite as much Borascu has been used this year as last, probably due to the shortage of straw. Most mills seem to have so little inventory they'll use it before the hot Summer season can cause deterioration. Comments from the various mills on the use of Borascu have been favorable, and I am particularly interested in obtaining data such as the type Howard Blandin has just given. I think Ball Brothers have collected some data.

E. M. PYATT (Ball Brothers Co.): We figured several different schemes, using two thirds of the borax on the top row and the other one third on the next row. We used 750 pounds of borax per 1000 square feet. This year we only treated three stacks as we knew we weren't going to keep all of them until next year. Tests on alkali solubilities showed borax had definite preservative properties.

MR. ARONOVSKY: We have found some correlation between deterioration and alkali solubility of the straw. Mel, you had some experience with this preservative work.

MR. KNACK: We haven't run any alkali solubilities on the preserved straw. We are thoroughly convinced that even though you keep straw only 1 year, preservation is very much worth while if only for the reason that handling is simplified so much. The bale ties don't break if borax is used.

MR. BUSH: We used borax on several stacks. The bales look good after a year in the stack, and they are well preserved. There was no growth of weeds. I thought it well worth while.

MR. ARONOVSKY: Has anyone any experience with a 20% loss of yield, as reported by Mr. Blandin?

MR. BLANDIN: Deterioration starts in April. I was interested in the sisalkraft cover but when I learned that is was good for only about a year, that took it out of the picture for us. Someone mentioned that, due to rains, the moisture went down to eight tiers. We found that it went down nine tiers in 6 weeks this year because of heavy rains.

MR. ARONOVSKY: Theoretically, it doesn't make any difference how deep the water seeps into the stack as long as it takes enough borax with it.

MR. LYON: We covered 10 stacks with sisalkraft, costing about $170 per stack, but it was a complete failure.

MR. SHATTO: We had the same experience as Mr. Bush. So far as we are concerned, we shall use Borascu. We cook our tops separately from rest of straw.

J. W. KASTETTER (Stone Container Corp.): We haven't been using very much straw and so used very little borax treatment this year.

J. R. LITTLE (Hinde and Dauch Paper Co.): We have used it on three stacks that look all right so far. We have had very heavy rainfall this year but not much grass has sprouted.

MR. BLANDIN: Stack tops that are treated are firm; on untreated, we sink to our hips.

MR. ARONOVSKY: We have had preservation work going on for 3 years now, so we should have a formal report on the work so far. I discussed this with Mr. Blandin and he suggested we should have Mr. White, who has been around mills and talked with the mill men, prepare a manuscript on preservation of straw with borax. Will you have this paper ready by February, Mr. White?

MR. WHITE: We will have it ready.

Raw Materials Classification Subcommittee

MR. ARONOVSKY: We have been doing some work on the various species of straw. So far the trend seems to be that our middle western straw is the best for both corrugating and fine paper pulp. The Nebraska-Kansas straw is only slightly

inferior. The white wheat straw of the West Coast is on a par with the Nebraska-Kansas straw. The North Dakota straws are somewhat more difficult to pulp and the strength characteristics are not up to those of the other straws. We have no data on the straw from the Texas and Oklahoma areas. I hope we shall have information on those straws for our next meeting.

MR. BUSH: Do you find in laboratory analysis more differences in straws by areas than by varieties?

MR. ARONOVSKY: I think varieties show more differences. Of course, it is very hard to determine whether the variation is due to differences in cultural conditions or to variety of the straw. We had one type of straw grown in 3 separate years on the same farm and found some variation. But the variation was not as great as between them and the hard winter wheat straws.

MR. BUSH: Has anyone had experience with pulping solid straw?

MR. ARONOVSKY: We have had no experience with solid-stem straw since we have only a few ounces of such straws obtained from experiment stations. We heard from England about a year ago that they are having some trouble with their straw pulps. They laid the blame to the fact that British farmers are importing Belgian and French varieties of straw which have a solid stem. The only straw with a more or less solid stem that is grown in this country is "Rescue" from Montana.

Pulping Subcommittee

MR. ARONOVSKY: Mr. Stahl resigned as chairman of the Pulping Subcommittee last February, and John Little has consented to take it over. The Pulping Subcommittee project, discussed at the Terre Haute meeting last year, was to determine what the mills are doing in calculating pulp yields. There was considerable discussion there, and the chairman of the subcommittee was requested to contact the mills for information, such as shrinkage of straw, shrinkage of paper, and so on.

MR. LITTLE: I shall send out a questionnaire to the mills.

MR. ARONOVSKY: I hope you will all fill out the questionnaire. Those who receive John's questionnaire should also give him some suggestions as to other problems to work on.

MR. KRANCHER: We should investigate the usage of waste paper. I don't know how you can figure yields now without metering devices.

MR. LITTLE: Most people use an arbitrary figure, and subtract 10 to 20% for waste paper.

MR. KRANCHER: We wait until the end of the year as we can't rely on day-to-day or monthly basis figures. We don't have a big inventory of waste paper but even then we are off 40 to 50 tons of paper each month. We check our inventory once a month.

MR. ARONOVSKY: How do you determine amount of straw you use? Do you take the moisture content of straw when it comes into the mills or when you take inventories? Some of you are using Delmhorst moisture meters and others are using Thwing testers. Are you satisfied with them? How difficult is it to make a rough spot check on moisture content of straw when the bales are brought to the rotary house?

MR. BUSH: We do that all the time by human judgment. We charge all of our rotaries with the same amount of dry straw. We take a record on a dry basis of all the straw going into the rotaries.

MR. KRANCHER: After the rain last January, the 50 or 60% moisture in farm stacks was out of range of the instrument.

MR. WILKINSON: We make the first check when the straw is stacked, then Adair checks the straw when it comes in, and goes into the rotary house. If there is trouble, we dry the whole bale in a superheated oven—24 hours' time at 150 pounds pressure—so we have a pretty good idea as to how the moisture content is running.

MR. ARONOVSKY: If everyone would weigh the straw, you would know how much fiber you have, and how much you put into the rotary.

MR. WILKINSON: I don't think anyone can get accurate results without weighing.

MR. SHATTO: We use a tester on straw received but we depend on someone's judgment in rotary rooms. We seem to do pretty well that way.

MR. BUSH: We use 5 tons dry straw per rotary. Sometimes we have a shipper who objects to our grading; then we make a test by drying the straw and weighing it again. We have found our graders come within 2 to 4% of the weight.

MR. KNACK: The normal procedure in most mills is to have a man who is responsible for grading the straw when it arrives in the mill. That man knows the average weight of straw from any specific locality. He is seldom wrong. He reports what he considers the dry weight of the bale because he knows what they should weigh with a 10% moisture allowance.

MR. WILKINSON: We will have an automatic valve to put in the exact amount of water.

MR. ARONOVSKY: I think there is only one way to obtain control, and that is by measurement. Chemical wood pulp mills have proved that accurate controls give better uniformity.

MR. WILKINSON: Chem-fiber operation is a good example. All they have in the digester room are instruments.

MR. ARONOVSKY: That's right; they have pretty good controls. Controls will give better uniformity both in product and production. You will all agree that you use more controls and are making a better product now than you did 15 years ago.

Board and Paper Manufacture Subcommittee

MR. ARONOVSKY: Mr. Knack will report on the activities of the Board and Paper Subcommittee.

MR. KNACK: We haven't done much. I think perhaps the group as a whole might be interested in a round-table discussion of operating problems in some of the mills. What is the feeling of the group in this?

MR. KRANCHER: Refining is the most important problem outside of cooking. We have a variety of equipment—if we pool our experience we might move along faster.

MR. SHEW: I suggest that the chairman of this subcommittee write to the various mills as to what their specific problem is, and when we come before this round table we can bring certain specific questions we should like answered.

MR. KNACK: I suggest we ask each mill to list problems, and then send the lists to everyone.

MR. FIORI: Free discussion is very worth while if we are to solve our problems, especially to us who drive 400 or 500 miles to the meeting. We should have as much information as possible on stock preparation systems, in other words, a complete analysis of different operations. You might say "we are making a better sheet of board," but then you might be using twice as much horsepower as the other mills.

MR. KNACK: As the mills submit the things they are interested in, we shall know what they want to discuss. I think the committee should decide on those of most general interest.

MR. FIORI: I thought Mr. Palm's speech yesterday morning was very good. I enjoyed learning about his strawboard mill operation.

D. L. OWEN (Hinde and Dauch Paper Co.): I think the answer to the whole thing is that all of us are using different types of equipment and trying to arrive at the same answer. We are all wondering what is the best way to handle these operations. Each one is "hopped up" about some particular type of equipment. Perhaps having discussions on these different types of equipment would benefit us all.

MR. WILKINSON: We all have different types of refining equipment and we think the one we use is "it." Why don't

we come prepared to talk from the standpoint of the efficiency of our best-liked equipment? I don't believe that freeness is the best gage, but it is the only one we have. I believe we should consider rate of horsepower usage per ton versus freeness.

Mr. Aronovsky: At Terre Haute meeting we had a whole session on refining and did a pretty fair job, but only the equipment manufacturers presented papers. I think we should have the people who use equipment give us their good and bad points. The manufacturers should be brought into the discussions as consultants. Thus we would get a good idea from the standpoint of operation of the equipment—maybe we are operating it wrongly.

Mr. Knack: A lot of differences in opinion will develop. But when you sit around and exchange ideas you can't help but benefit. The committee will get together and select those subjects uppermost in the minds of the operators.

Mr. Palm: I think the method of approach is good. In our board group in the Canadian setup we have a number of these discussions. We tried several different methods to get discussion going. On several occasions difficulties were experienced until we decided to send out the questions first to find what problems were of interest to the various people. These questions were compiled and a listing sent out again prior to the meeting. This gave the mills time to think the problem over. It even gave people ideas they hadn't thought of before.

Mr. Hart: I believe that it is the practice for those who ask the question to lead the discussion on that particular subject.

Mr. Blandin: I think the time is right for such discussions. Some of us have new equipment. By the next meeting we should know some of the answers.

Mr. Knack: I think we should send the questionnaire out 3 to 6 months before the meeting. Our problems may be different then than they are now.

Mr. Balfour: Perhaps we could learn from the second sending out of the questionnaire just how they handle equipment at each mill. Then everyone would have a general idea.

Mr. Little: How about a flow diagram of each mill?

Mr. E. R. Carpenter: That's quite a job. How big a staff will Mel have to help him?

Mr. Krancher: The best approach to this problem is, I believe, to have at the time of this discussion handsheets of pulp and paper to illustrate the product from each mill. I think we can reconcile differences in results from refining conditions through visual means. Wonderful results from equipment may be only one man's opinion.

Mr. Fiori: The flow sheet of your processing equipment will give the information on what kind of sheet you are sending to the box shop and what kind of box you are making. I think it is the result that you get from a *group* of equipment that gives information on the final product.

Mr. Shew: I had in mind a specific phase we are having trouble with—the other fellows who will get the question can show us what they are doing on this problem.

Mr. Knack: You should have enough questions to get the discussion started. After the questions have come in, we can find out what we should discuss; we can't know now what form it will take. Probably the interest should be on refining but I think if someone has something bothering them in some part of their operation, we should discuss that too.

Mr. Aronovsky: Everyone agrees that we should have a round-table discussion at our next Fall meeting, with emphasis on refining. Questions will be sent to all of you and all of the questions, with your replies, will again be sent to you and they will then be taken up at the meeting.

Mr. Knack: I think that will be a good way to start it.

Testing Subcommittee

Mr. Aronovsky: Mr. Wilson, chairman of the Subcommittee on Testing, was unable to be here, but I can report that he spent considerable time on a laboratory corrugator. This is a machine to test your paper at the reel in order to tell what that sheet will do in the box factory.

(R. E. Green of the Thwing-Albert Instrument Co. is here and will demonstrate the latest model of his laboratory corrugator. Mr. Green made several successful corrugating trials in the laboratory unit on commercial corrugating paper, and he pointed out the advantages of this laboratory tester which is now being manufactured by his company.)

Mr. Krancher: Have you checked the moisture content of the corrugated board sample?

Mr. Green: It is practically moisture free. You can tell by the color, and also by the amount of condensation on the hold-down plate.

Mr. Aronovsky: Would it be possible to take the paper off the reel, put it in a seasoning box kept at a definite relative humidity, and make the test without additional wetting?

Mr. Green: This sheet had more moisture than you would have in an unwetted sheet.

Mr. Krancher: Some people have one steam spray on the machine and some have as many as five. Would wetting like this (submerging) be representative of box shop practice?

Mr. Green: It would seem to me that unless you have definite requirements for the moisture content of the sheet you should have additional moisture in the test sample.

Mr. Wilkinson: We find very little moisture taken on by the sheet at the corrugator. Our sheets have about 7.5% water regardless of the amount of steam we give them.

Mr. Zinkil: Doesn't the steam act as a lubricant on the corrugator?

Mr. Knack: Does the corrugating test sheet give you good correlation?

Mr. Wilkinson: This will give us a little higher test than off the corrugator. If you have relatively good sheets off this tester, you know you will have a good sheet off the corrugator. A poor sheet off the tester means a poor sheet off the corrugator.

Mr. Zinkil: What about ring test and corrugator correlation?

Mr. Wilkinson: None.

Mr. Palm: Do you immerse the sheet for a given time?

Mr. Wilkinson: No, we put it between two wet blotters.

Mr. Green: TAPPI recommends putting the wet sheet between two blotters.

Mr. Wells: We must have a program of correlation; then we shall have the answer. The next important step is to correlate the information from this corrugator and from the finished product. Board dried in an oven is stronger than drier-dried and reeled board. Bolton 2 years ago pointed out that you have to put the sample under the same kinds of stress that are encountered in commercial corrugating.

Mr. Green: Will any two corrugating machines give the same stress? A good possibility of this machine is not only to evaluate the straw but also to know whether your corrugating machine is working properly.

Mr. Aronovsky: You must use a standard liner and standard adhesive. You can't take just any liner and any adhesive and expect to get consistent results.

Mr. Green: First model of this tester was sold in South Africa.

(W. J. Delmhorst, of the Delmhorst Instrument Co., Boonton, N. J., then showed his newly designed moisture detector, smaller and more convenient to handle. He listed several uses for meters in connection with the manufacture of paper and boxboard; moisture in baled straw, in baled scrap, in paper in rolls, in paper as manufactured, and in single sheets.)

Mr. Knack: Would the instrument that we have for checking straw be okay for testing paper right off the machine?

Mr. Delmhorst: We should have to use flat electrodes applied to opposite sides of the sheet.

W. A. Phillips (Weston Paper and Mfg. Co.): What

about the difference in static electricity coming off the machine? Will that affect the reading?

MR. DELMHORST: Yes, in an excessively dry sheet, but most of it could be grounded off by a guard circuit.

E. R. CARPENTER: I am sure we all would be interested in a roller-type instrument if we could get a good reading from it.

MR. SHATTO: In spot checking of the sheet, do I understand you to say that the four-prong electrode can be used on a roll?

MR. DELMHORST: Yes, it is especially useful in picking out wet streaks.

MR. SHATTO: Do I need the new machine?

MR. DELMHORST: The old machine will do, equipped with a four-prong electrode.

MR. BLANDIN: Is the case moistureproof?

MR. DELMHORST: No, but it is more moisture-resistant than the old case. The point is the only part of the high potential circuit that is not shielded.

Plans for 1951 Meetings

The chairman then called for discussion on the possible site for the 1951 Fall meeting of this group. He pointed out that, in accordance with custom, the 1951 meeting should be held at a mill site. The city chosen should have hotel accommodations for 60 to 80 people, and a room large enough to accommodate this number for a meeting. Coshocton, Ohio, Vincennes, Ind., and Monroe, Mich., were eliminated from consideration for 1951 because of present lack of hotel space.

The chairman then thanked the speakers for their efforts in preparing papers for this meeting, and all of the members of TAPPI and guests for active participation in the frank and interesting discussions. He also thanked the Director and staff of the Northern Laboratory for their assistance and courtesy and for the use of the Laboratory in making this meeting so successful.

After adjournment, many of those attending made a tour of the Northern Laboratory, and of the Keystone Steel and Wire Co., Bartonville, Ill.

Those attending the 1950 Peoria meeting were:

Agronin, T., Chief Engineer, Shartle Brothers Machine Co., Middletown, Ohio
Anderson, R. J., Manager Farm Department, Sisalkraft Co., Chicago, Ill.
Atchison, J. E., Chief, Pulp and Paper Branch, Economic Cooperation Administration, Washington, D. C.
Augustine, F. E., Superintendent of Board Mill, Gaylord Container Corp., Bogalusa, La.
Ayers, J. R., Sales, E. D. Jones and Sons Co., Pittsfield, Mass.
Balfour, N. S., Chemical Engineer, Alton Box Board Co., Alton, Ill.
Blandin, H. M., Technical Director, Central Fibre Products Co., Quincy, Ill.
Bush, V. E., Plant Manager, Hinde and Dauch Paper Co., Fort Madison, Iowa
Carpenter, E. R., Plant Engineer, Weston Paper and Manufacturing Co., Terre Haute Division, Terre Haute, Ind.
Carpenter, N. H., Assistant Superintendent, Muskingum Fiber Products Co., Coshocton, Ohio
Converse, C. W., Sales Manager, Pulp and Paper Mill Division, Sprout, Waldron and Co., Inc., Muncy, Pa.
Coray, W. G., Sales Engineer, Pacific Coast Borax Co., Chicago, Ill.
Crook, J. F., Sales, J. W. Bolton and Sons, Inc., Lawrence, Mass.
Dawson, C. E., Assistant Superintendent, Dresden Paper Mills Co., Dresden, Ohio
Delmhorst, W. J., President, Delmhorst Instrument Co., Boonton, N. J.
Dill, R. R., Salesman, Bauer Brothers Co., Springfield, Ohio
Dunlop, G. A., Manager, Ohio Straw Co., Coshocton, Ohio
Eberhardt, L., Design Engineer, Bauer Brothers Co., Springfield, Ohio
Espenmiller, H. P., Research Engineer, Dilts Machine Works, Fulton, N. Y.
Fahlgren, S., Sales Engineer, Bird Machine Co., South Walpole, Mass.
Fiori, J. J., General Manager Mill Operations, Stone Container Corp., Chicago, Ill.
Fuko, J., Assistant Chemist, River Raisin Paper Co., Monroe, Mich.
Ginaven, M. E., Sales Manager, Bauer Brothers Co., Springfield, Ohio
Green, R. E., Sales Engineer, Thwing-Albert Instrument Co., Philadelphia, Pa.
Hammond, W. E., Assistant Economist, University of Nebraska, Lincoln, Neb.
Harbrecht, W. L., Assistant Superintendent of Mills, Hinde and Dauch Paper Co., Sandusky, Ohio
Hart, J. S., Research Associate, Pulp and Paper Research Institute of Canada, Montreal, Canada
Herman, L. F., Engineer, Gruendler Crusher and Pulverizer Co., St. Louis, Mo.
Kastetter, J. W., Superintendent, Stone Container Corp., Coshocton, Ohio
Knack, M. F., Technical Director, River Raisin Paper Co., Monroe, Mich.
Krancher, C. G., Manager, Ball Brothers Co., Noblesville, Ind.
Larson, O. E., Engineer, The Emerson Manufacturing Co., Lawrence, Mass.
Little, J. R., Chemist, Hinde and Dauch Paper Co., Sandusky, Ohio
Lyon, H., Straw Buyer, Weston Paper and Manufacturing Co., Terre Haute Division, Terre Haute, Ind.
Macdonald, R. G., Secretary-Treasurer of TAPPI, New York, N. Y.
Morgan, M. W., Sales Engineer, Wallace and Tiernan Co., Chicago, Ill.
Morris, R. M., Jr., Chief Chemist, Container Corp. of America, Circleville, Ohio
Owen, D. L., General Superintendent of Mills, Hinde and Dauch Paper Co., Sandusky, Ohio
Palm, W. H., Assistant to General Manager, Hinde and Dauch Paper Co. of Canada, Ltd., Toronto, Ont., Canada
Phillips, W. A., Chemist, Weston Paper and Manufacturing Co., Terre Haute Division, Terre Haute, Ind.
Porter, R. W., Editorial Director, *The Paper Industry*, Chicago, Ill.
Price, C. V., Chief, Nebraska Resources Committee, Lincoln, Neb.
Pyatt, E. M., Chemist, Ball Brothers Co., Noblesville, Ind.
Rankin, M. L., Sales Representative, Taylor, Stiles and Co., Riegelsville, N. J.
Root, F. A., Salesman, Clinton Foods, Inc., Clinton, Iowa
Sapp, J. E., Chemical Engineer, Gaylord Container Corp., Bogalusa, La.
Schroeder, H. J., Assistant Superintendent, Container Corp. of America, Circleville, Ohio
Shatto, H. J., Mill Manager, Fort Wayne Corrugated Paper Co., Vincennes, Ind.
Shelton, H. J., Vice-President, Gruendler Crusher and Pulverizer Co., St. Louis, Mo.
Shew, R. W., General Superintendent, Ball Brothers Co., Noblesville, Ind.
Shouvlin, R. J., Sales, Bauer Brothers Co., Springfield, Ohio
Sigwardt, C., Research, Celotex, Chicago, Ill.
Smiley, L. D., Manager, Pulp and Paper Division, Gruendler Crusher and Pulverizer Co., St. Louis, Mo.
Snyder, E. A., Sales Engineer, Rice Barton Research Corp., Worcester, Mass.
Springer, R. A., Technical Service, Diamond Alkali Co., Cleveland, Ohio
Stanley, T. W., General Superintendent, Dresden Paper Mills Co., Dresden, Ohio
Thornton, J. S., Sales Engineer, Downingtown Manufacturing Co., Dowingtown, Pa.
Wells, S. D., Research Associate, Institute of Paper Chemistry, Appleton, Wis.
Wheeler, H. R., Jr., Technical Sales Service, Clinton Foods, Inc., Clinton, Iowa
White, C. W., Chemical Engineer, Pacific Coast Borax Co., Cleveland, Ohio
Wilkinson, R. M., Chemist, Alton Box Board Co., Alton, Ill
Zinkil, G. A., Central Fibre Products Co., Quincy, Ill.

Northern Regional Research Laboratory

Aronovsky, S. I., In Charge, Pulp and Paper Section, Agricultural Residues Division
Ernst, A. J., Paper Technologist, Agricultural Residues Division
Jordan, G. F., Technical Editor
Lathrop, E. C., Head, Agricultural Residues Division
Milner, R. T., Director
Naffziger, T. R., Chemical Engineer, Agricultural Residues Division
Nelson, G. H., Chemical Engineer, Agricultural Residues Division
Sutcliffe, H. M., Chemist, Agricultural Residues Division

Oil Content of Petroleum Waxes

TAPPI Suggested Method T 636 sm-51

(THIS SUGGESTED METHOD IS UNDER THE JURISDICTION OF THE WAX TESTING COMMITTEE)

THIS method describes a procedure for the determination of the amount of oil in petroleum waxes having melting points of 105°F. or higher and containing not over 15% of oil. (The method is being used by some laboratories for waxes of lower melting point and higher oil content.) The sample is dissolved in methylethylketone, the solution cooled to −25°F. to precipitate the wax, and filtered. The oil content of the filtrate is determined by evaporating the solvent and weighing the residue.

This is a modification of the Tentative Method of Test for Oil Content of Paraffin Wax, ASTM Designation: D 721–51 T. It is based upon the method described by Lee and Kalichevsky (*1*) which became the ASTM Standard Method of Test for Oil Content of Paraffin Wax in 1944 and has since been generally accepted by producers and consumers of paraffin wax. This same basic procedure has been extended to the determination of oil in microcrystalline wax, as well as paraffin wax. When applied to microcrystalline wax, however, the oil content values obtained must be considered only arbitrary values where "oil" is defined by the conditions of the test.

APPARATUS

1. *Filter Stick and Assembly*, consisting of a 10-mm. diameter, medium-porosity, sintered-glass filter stick, provided with an air pressure inlet tube and delivery nozzle. It is provided with a ground-glass joint to fit a 25 by 170-mm. test tube. The dimensions for a suitable filtration assembly are shown in Fig. 1.

Note: A metallic filter stick may be employed if desired. One made of stainless steel and having a $^1/_2$-inch disk of medium porosity has been found to be satisfactory. The metallic apparatus is inserted into a 25 by 150-mm. test tube and held in place by means of a cork.

2. *Cooling Bath*, consisting of an insulated box with 1-inch holes in the center to accommodate any desired number of test tubes. The bath may be filled with a suitable medium, such as kerosene, and may be cooled by circulating a refrigerant through coils, or by using solid carbon dioxide. A suitable cooling bath to accommodate three test tubes is shown in Fig. 2.

3. *Dropper Pipet*, provided with a rubber bulb, and calibrated to deliver 1 ± 0.05 gram of molten wax.

4. *Transfer Pipet* for solvent, calibrated to deliver 15 ± 0.06 ml.

5. *Air Pressure Regulator*, designed to supply air to the filtration assembly at the volume and pressure required to give an even flow of filtrate. Either the conventional pressure-reducing valve or a mercury bubbler-type regulator has been found satisfactory. The latter type, shown in Fig. 3, consists of a 250-ml. glass cylinder and a T-tube held in the cylinder by means of a rubber stopper grooved at the sides to permit the escape of excess air. The volume and pressure of the air supplied

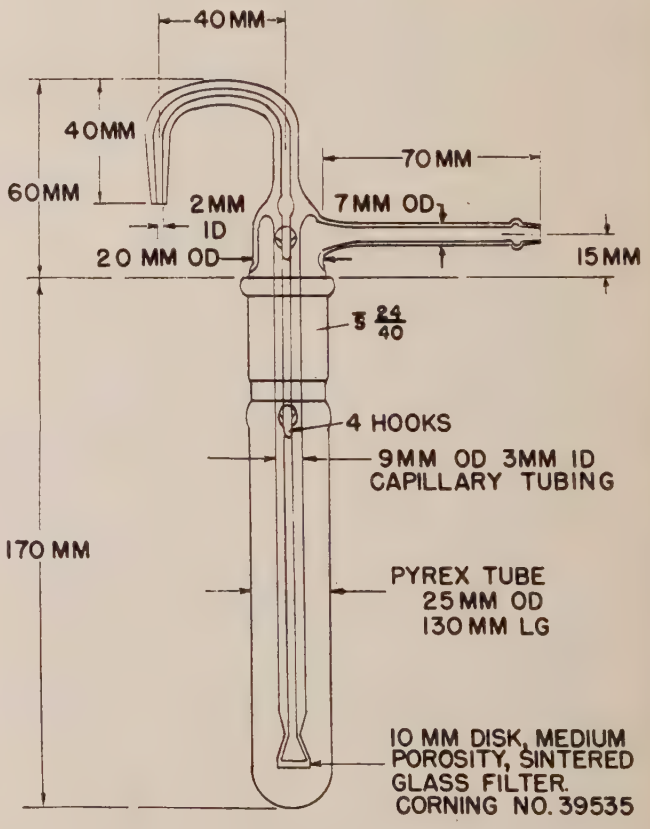

Fig. 1. Filter stick and assembly

This method is suggested by the Standards Committee as being the most suitable to date. It is *not*, however, a TAPPI Standard. Criticisms are earnestly requested and should be sent to R. G. Macdonald, Secretary, Technical Association of the Pulp and Paper Industry, 122 East 42nd Street, New York 17, N. Y.

to the filtration assembly are regulated by the depth to which the T-tube is immersed in mercury at the bottom of the cylinder. Absorbent cotton placed in the space above the mercury prevents loss of mercury by spattering. The air pressure regulator is connected to the filter stick and assembly by means of rubber tubing.

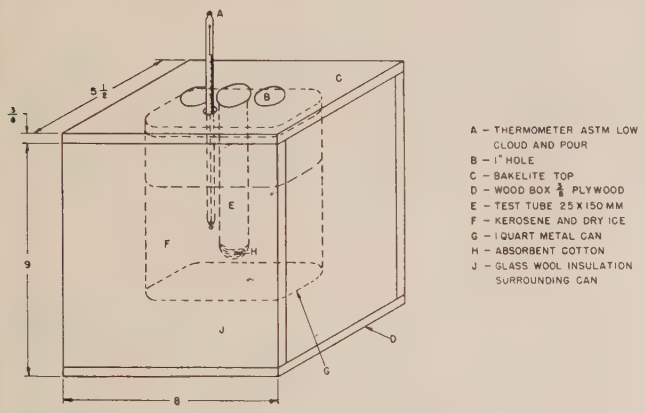
A – THERMOMETER ASTM LOW CLOUD AND POUR
B – 1" HOLE
C – BAKELITE TOP
D – WOOD BOX ¾ PLYWOOD
E – TEST TUBE 25 X 150 MM
F – KEROSENE AND DRY ICE
G – 1 QUART METAL CAN
H – ABSORBENT COTTON
J – GLASS WOOL INSULATION SURROUNDING CAN

Fig. 2. Cooling bath

6. *Oil-in-Wax Thermometer*, having the following specifications:

Temperature range	−35 to +70°F.
Immersion	3-inch
Subdivisions	1°F.
Longer graduation lines at each	5°F.
Graduations numbered at each multiple of	10°F.
Scale error at any point when standardized shall not exceed	0.5°F.
Total length	350 to 355 mm.
Stem diameter	7.5 to 8.5 mm.
Bulb diameter	6 to 7 mm.
Bulb length	15 to 20 mm.
Bottom of bulb to graduation line at	−35°F.
Distance	170 to 185 mm.
Top of thermometer to graduation line at	70°F.
Distance	45 to 60 mm.
Expansion chamber	To 212°F.
Top finish	Plain

The thermometer shall be standardized for 3-inch immersion at the following points: −30, 0, 32, 70°F., and average temperature of 70°F. of emergent mercury column.

7. *Weighing Bottle*, conical in shape and glass stoppered, having a capacity of 15 ml.

8. *Evaporation Assembly*, consisting of an evaporating cabinet and connections, essentially as shown in Fig. 4, and capable of maintaining a temperature of 95 ± 2°F. around the evaporation flasks. Construct the jets with an inside diameter of 4 ± 0.2 mm. for delivering a stream of clean, dry air vertically downward into the weighing bottle. Support each jet so that the tip is 15 ± 5 mm. above the surface of the liquid at the start of the evaporation. Supply air at the rate of 2 to 3 liters per minute per jet, purified by passage through a tube of 1-cm. bore packed loosely to a height of 20 cm. with absorbent cotton. Periodically check the cleanliness of the air by evaporating 4 ml. of methylethylketone by the procedure. When the residue does not exceed 0.1 mg., the evaporation equipment is operating satisfactorily.

9. *Analytical Balance*, capable of reproducing weights to 0.1 mg. The sensitivity should be adjusted so that 0.1 mg. deflects the pointer ½ division on the pointer scale.

10. *Wire Stirrer*. A piece of stiff iron or nichrome wire of about No. 20 B & S gage, 250-mm. long. A 10-mm. diameter loop is formed at each end and the loop at the bottom end is bent so that the plane of the loop is perpendicular to the wire.

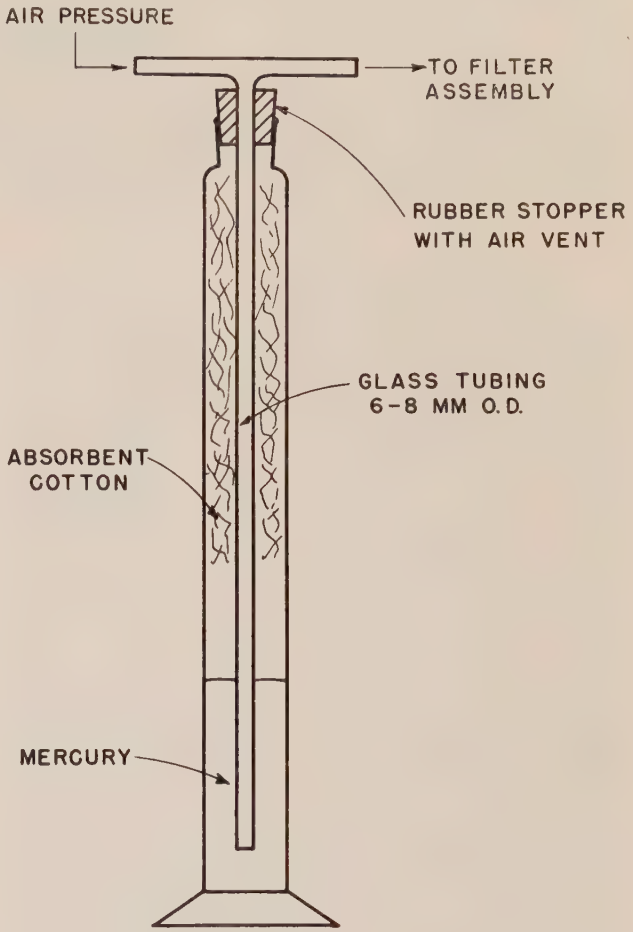

Fig. 3. Air pressure regulator

SOLVENT

Methylethylketone, conforming to the following specifications:

Specific gravity at 20/20°C.	0.805 to 0.807
Refractive index at 20°C.	1.376 to 1.380
Color	Water white
Distillation range	
Below 78°C.	None
Above 81°C.	None
Odor	Characteristic, nonresidual
Water	Miscible without turbidy with 19 volumes of heptane at 20°C.
Nonvolatile	Not over 0.1 mg. in 4 ml. when evaporated as described in the last paragraph under Procedure

TEST SPECIMEN

If the sample of wax is 2 pounds or less, obtain a representative portion by melting the entire sample and

stirring thoroughly. For larger samples exercise special care to insure obtaining a truly representative portion, bearing in mind that the oil may not be distributed uniformly throughout the sample, and that mechanical operations may express some of the oil.

PROCEDURE

Melt a representative portion of the sample in a beaker, using a water bath or oven maintained at 85 ± 14°C. (185 ± 25°F.). As soon as the wax is completely melted, thoroughly mix by stirring. Preheat the dropper pipet in order to prevent the solidification of wax in the tip, and withdraw a 1-gram portion of the sample as soon as possible after the wax has melted.

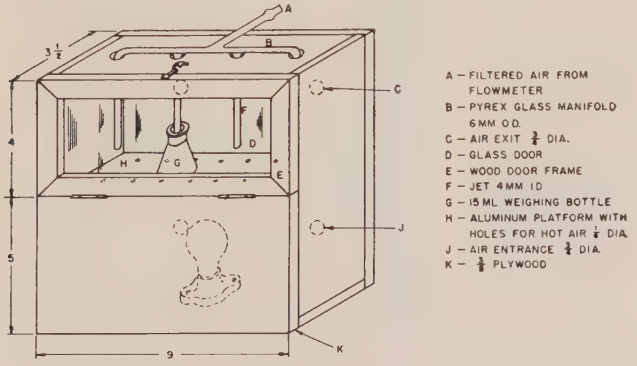
A – FILTERED AIR FROM FLOWMETER
B – PYREX GLASS MANIFOLD 6MM O.D.
C – AIR EXIT ¾ DIA.
D – GLASS DOOR
E – WOOD DOOR FRAME
F – JET 4MM I.D.
G – 15 ML. WEIGHING BOTTLE
H – ALUMINUM PLATFORM WITH HOLES FOR HOT AIR ¼ DIA.
J – AIR ENTRANCE ¾ DIA.
K – ¾ PLYWOOD

Fig. 4. Evaporator

Hold the pipet in a vertical position and carefully transfer its contents into a clean, dry test tube previously weighed to the nearest 1 mg.

Note: The weight of a test tube which is cleaned by means of solvents will not vary to a significant extent; therefore, a tare weight may be obtained once and used repeatedly.

Pipet 15 ml. of methylethylketone into the test tube, and place the latter just up to the level of its contents in a steam or water bath. Heat the solvent-wax mixture, stirring up and down with the wire stirrer until a homogeneous solution is obtained. Exercise care to avoid loss of solvent by prolonged boiling.

Note: Very high-melting microcrystalline wax samples may not form clear solutions. In such cases, stir until the undissolved material is well dispersed as a fine cloud.

Plunge the test tube into an 800-ml. beaker of ice water and continue to stir until the contents are cold. Remove the stirrer, then remove the test tube from the ice bath, wipe dry on the outside with a clean, dry cloth and weigh to the nearest 0.1 gram.

Note: During this operation the loss of solvent through vaporization should be less than 1%. The weight of the solvent is therefore practically a constant and, after a few samples are weighed, this weight, approximately 11.9 grams, can be used as a constant factor.

Place the test tube containing the wax-solvent slurry in the cooling bath which is maintained at −30 ± 2°F. During this chilling operation it is important that stirring by means of the thermometer be almost continuous in order to maintain a slurry of uniform consistency as the wax precipitates. Do not allow the wax to set up on the walls of the cooling vessel nor permit any lumps of wax crystals to form. Continue stirring until the temperature reaches −25 ± 0.5°F.

Immerse in the mixture the clean, dry filter stick, which has previously been cooled by placing in a test tube and holding at −30 ± 2°F. in the cooling bath for a minimum of 10 minutes. Seat the ground-glass joint of the filter so as to make an airtight seal. Place an unstoppered weighing bottle, previously weighed together with the glass stopper to the nearest 0.1 mg., under the delivery nozzle of the filtration assembly.

Note: Take every precaution to insure the accuracy of the weight of the stoppered weighing bottle. Prior to determining this weight, rinse the clean, dry weighing bottle and stopper with methylethylketone, wipe dry on the outside with a cloth and place in the evaporation assembly to dry for about 5 minutes. Then remove the weighing bottle and stopper, place near the balance and let stand for 10 minutes prior to weighing. Stopper the bottle during this cooling period. Once the weighing bottle and stopper have been dried in the evaporation assembly, lift only with forceps. Take care to remove and replace the glass stopper with a light touch.

Apply air pressure to the filtration assembly and immediately collect about 4 ml. of filtrate in the weighing bottle. Release the air pressure to permit the liquid to drain back slowly from the delivery nozzle. Remove the weighing bottle immediately, stopper and weigh to the nearest 10 mg. without waiting for it to come to room temperature. Unstopper the weighing bottle and place under one of the jets in the evaporation assembly maintained at 34 ± 1°C. (95 ± 2°F.) with the air jet centered inside the neck and the tip 15 ± 5 mm. above the surface of the liquid. After the solvent has evaporated, which usually takes less than 30 minutes, remove the bottle, insert the stopper, and place near the balance. Let stand for 10 minutes and weigh to the nearest 0.1 mg. Repeat the evaporation procedure, using a 5-minute instead of a 30-minute evaporation period, until the loss between successive weighings is not over 0.2 mg.

REPORT

Calculate the percentage, P, of oil in the wax by means of the following equation and report the result to two decimal places:

$$P = \frac{100\,AC}{BD} - 0.15;$$

where,

A = weight of oil residue, grams;
B = weight of wax sample, grams;
C = weight of solvent, grams, obtained by subtracting weight of test tube plus wax sample from weight of test tube plus wax and solvent;
D = weight of solvent evaporated, grams, obtained by subtracting weight of weighing bottle plus oil residue from weight of weighing bottle plus filtrate.

Note: The figure 0.15 is an average factor correcting for the solubility of wax in the solvent at −25°F.

PRECISION

Results should not differ from the mean by more than the following amounts:

Oil in wax	*One operator and apparatus*	*Different operators and apparatus*
Under 1%	0.1	0.2
1% or over	0.2	0.4

LITERATURE CITED

1. Lee, R., and Kalichevsky, V. A., *Ind. Eng. Chem., Anal. Ed.*, 14: 767 (1942).

Instrumentation Studies. LXV. A Study of Photoelectric Instruments for the Measurement of Color: Reflectance and Transmittance

IX. The Hunter Color and Color-Difference Meter

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The Hunter Color and Color-Difference Meter (HCDM) is designed to measure color and small color differences by means of the three-filter photoelectric method of colorimetry. The HCDM is arranged to yield data in terms of Hunter's color diagram, in which a unit of color difference is intended to correspond to a uniform difference in color perception throughout the color solid. The I.C.I. tristimulus values are not determined. The HCDM is intended to be used for color control, and cannot be employed for the determination of spectral reflectance curves, or for the measurement of papermakers' brightness. The values of R_d, a, and b are measured by reference to a color standard having colorimetric characteristics similar to those of the sample. The basic question for the program is, "Is the instrumental indication of a color match valid and sufficiently sensitive and, if a mismatch is indicated, is the direction of the calculated difference accurate?" In the discussion of this question, the performance of an imperfect color matching instrument is compared with that of a person with defective color vision. In either case, a good result might be obtained if the standard and the sample have spectral reflectance curves of very nearly the same form (nonmetameric); however, unsatisfactory matching might result if these curves cut across each other (metameric). Unfortunately, the color curves of typical production are metameric, so that it does not follow that a defective instrument will necessarily yield satisfactory results when the standard and sample are of similar color. The major portion of the program was devoted to a testing of the performance of the HCDM on colors of accurately known characteristics, to the end that the data might be of assistance to a potential user of the HCDM in answering the above question as it relates to his problems of color control. This paper presents the results of tests on such rudimentary factors as sensitivity, response to infrared radiation, effect of stray light, angles of incidence of the light beams, and linearity of response. The HCDM is well designed with respect to these factors. Data are given on the performance of the instrument in color matching. In tests on a series of white papers, two difficulties appeared. First, the instrumental errors were fairly large, so that one presumably cannot simply use a "white" standard when measuring the color of white paper, but should employ a standard having spectral reflectance almost identical with that of the paper. Second, some of the instrumental errors were unduly large, even when allowance was made for the fact that there were substantial differences between the color curves for the standard and samples. In two cases the errors, when translated to least perceptible color differences, were, respectively, about 10 and 15 color steps. It is shown that the probable cause of these large discrepancies is a mismatch of the blue response function of the HCDM to that theoretically required; the centroid wavelength of this function appears to be too short. In order that uncertainties attributable to differences in geometries between instruments might be eliminated, a major part of the work was done with transmitted light. The tests included complete spectrophotometric determinations and integrations to obtain I.C.I. tristimulus values for several families of transparent materials, as follows: seven glass and three Wratten filters, a subset from this group of four yellow filters, a family of Victoria green solutions, a family of Chrysoidine solutions, a family of auramine solutions, a family of Fast red 8BL solutions, and a family of copper sulphate solutions. In most cases, the families were of spectral transmission curves of similar shape (nonmetameric). However, large errors were observed, in some cases even when the curves for the reference standard and the sample were not far apart. Most of the errors could be attributed to a mismatch of the blue response function of the HCDM to that required. It appeared that the centroid wavelength for this function was about 10 millimicrons too short. The errors in the a scale were not negligible, although smaller, but could not readily be associated with wavelength error; they were attributed to errors in the adjustment of photocell response and of the circuit. Data on two families of papers, for which it happened that the b values were numerically small, were in good accord with the calculated values of R_d, a, and b. This better agreement is taken as an indication of the possibility of the generally better performance of the HCDM that might be obtained through elimination or substantial reduction of the errors which the examined instrument suffered.

THERE are two principal methods for using photoelectric instruments designed to measure color. The first might be described as the research or analytical method; instruments permitting the use of this method yield monochromatic or nearly monochromatic reflectance (or transmission) and, hence, also, a spectral reflectance (or transmission) curve. Instruments that are suitable for this method (e.g., recording spectrophotometers and abridged spectrophotometers or reflection meters) are most widely used for industrial control of color and for research and technical purposes. Such instruments suffer only one major shortcoming: Where one is concerned *only* with the routine control of color, *and does not require that the instrument will furnish data that would be of aid in analyzing a mis-*

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match, too much time is required to obtain colorimetric data (I.C.I. tristimulus values) from a spectral reflectance curve.

It was because of this difficulty that three-filter photoelectric colorimeters came into existence a number of years ago. In properly designed instruments of this class the spectral qualities of the light source, glass

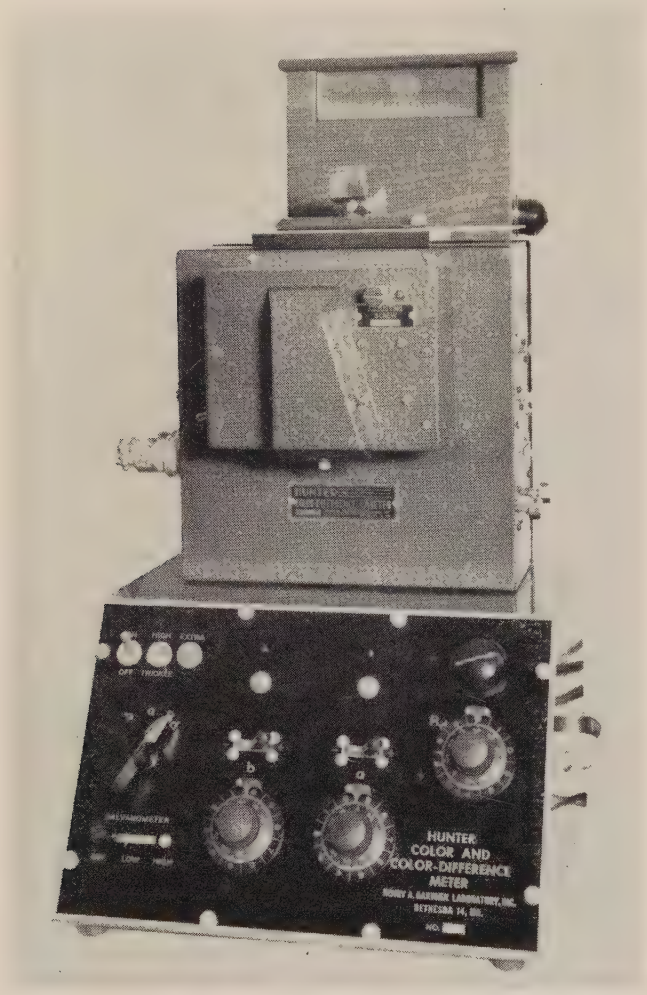

Fig. 1. The Hunter Color and Color-Difference Meter

optics, filters, and photocells are chosen in such manner that the three instrumental responses are proportional to, or are predetermined functions of, the I.C.I. tristimulus values X, Y, and Z. One may regard such instruments as rapid computers, because they automatically evaluate such integrals as $\int_0^\infty ExRd\lambda$, which are encountered in colorimetry by the spectrophotometric method. If instruments of this second class are properly designed and are accurate, they should yield information on color matching in accord with that of the I.C.I. standard observer.

A detailed discussion of the principles of photoelectric color instruments and a condensed presentation of the I.C.I. system of color specification will be found in Part I of this report (*1*); the reader may find it convenient to have a copy of this report on hand. Also, because of its intimate connection with the present work, the reader may wish to refer to Part IV of this report (*2*), which covers the instrumentation study of the Hunter Multipurpose Reflectometer. Those interested in the theory of three-filter photoelectric colorimeters may wish to read a discussion published by Van den Akker (*3*) on the limitations of the best physically realizable three-filter colorimeter.

The instrument of the present study is basically a three-filter photoelectric colorimeter. Although it is not designed to measure directly the tristimulus values, it incorporates the three-filter principle in such manner that color and color differences may be rapidly determined on color scales which employ the NBS unit of color difference evolved by Judd (*4*). Judd designed this unit so that it would correspond to approximate perceptual uniformity of color difference throughout the color solid; he so adjusted the value of the unit as to make it correspond to the maximum color difference that would be tolerated in the commercial matching of colors. (This unit is very appreciably larger than that corresponding to the least difference in color that can be perceived under good conditions by an experienced observer, the latter being of the order of 0.3 NBS unit.) According to the "Description and Instructions for Hunter Color and Color-Difference Meter," issued by the manufacturer, "The Hunter Color and Color-Difference Meter has been designed for the rapid and precise measurement of color and small color differences." This instrument can be employed only for color matching and the control of color. It is not possible to employ the instrument for the measurement of brightness (papermakers') or for any other reflectance other than luminous reflectance, and, hence, it is not possible for the instrument to yield a spectral reflectance curve. However, under certain conditions the instrument might speedily yield information that is sufficiently accurate for the purposes of industrial color control. It is the purpose of this work to study the instrument and to establish at least a portion of the basis needed to evaluate the merits and limitations of the Color and Color-Difference Meter.

SECTION I. DESCRIPTION OF THE INSTRUMENT

Only a brief description of the Color and Color-Difference Meter will be given here because Hunter has described the instrument in detail (*5*). The following material is further quoted from the "Description and Instructions for Hunter Color and Color-Difference Meter." "...The instrument is a photoelectric tristimulus colorimeter measuring color on three scales closely resembling the L, a, and b scales which give uniform measures of the perceptibility of differences between colors. In the new apparatus, photocell windows and the measuring circuits have been selected so that the three values of color are read directly from the ten-turn potentiometer rheostats. When these three rheostats are set to the values of some standard color and a specimen of somewhat similar color is placed in exposure position, deflections of the current-detecting galvanometer then show the magnitude of the three scales of the color difference between the specimen and the standard.

"The new apparatus shown in Fig. 1 is divided into two parts. The upper part is the exposure unit containing light source, mounting for the test specimens, and the means for viewing specimens with different photocells. The lower part is the measuring unit con-

taining potentiometer rheostats, switches, and other components for recording values of photocell current on scales proportional to color.

"... In the exposure unit are an automobile-spotlight lamp and lenses and mirrors for projecting two beams of light from this lamp onto the test specimen mounted on top. These beams strike the surface of this specimen from opposite directions along axes that are 45° from perpendicular.

"A comparison photocell near the source is constantly lighted by it. The current generated by this photocell is taken to the measuring unit where the various currents from the test photocells are measured against it. Because currents from photocells illuminated from a common source are thus intercompared, change of source intensity does not affect instrument results. However, change of source color that normally accompanies change of source intensity does affect measured color and it is therefore necessary to operate the lamp at a constant potential maintained by a battery or by an electronic-type constant-voltage source.*

"Light reflected from the test specimen in perpendicular and near-perpendicular directions is measured. A fluted (Fresnel) lens is used to collect this light from the specimen and direct it into the diffusing enclosure... This diffusing enclosure is lined inside with magnesium oxide, a nonselective, nearly perfect white. ... There are five windows around the wall of this enclosure. Through these windows the photocells covered by filters receive light.

"To adapt it to specimens of different types, the exposure unit may be moved to different positions. It may be tipped 90° forward to place the specimen in a vertical plane just above the instrument panel. The exposure unit may also be removed from the frame which fastens it to the measurement unit and mounted anywhere within cable distance.

"... The area of specimen normally illuminated is oval in shape, about $2^1/_4$ inches long, and $1^1/_2$ inches wide. Where specimens have small area, condensing lenses can be installed in the manner shown ... and the light confined to an area which is at a minimum about $^3/_8$ by $^1/_4$ inch. By changing source lenses, illumination can be further concentrated into areas less than $^1/_4$ inch in diameter.

"In the measurement unit the test currents obtained from the exposure unit are measured with three separate ten-turn potentiometer rheostats in terms of the current obtained from the constantly illuminated comparison photocell. The circuit and its operation are described in detail [by Hunter (*5*)]. A major feature of this circuit is the manner in which currents from the photocell pairs responding to the chromatic dimensions of color are adjusted to correspond to visual sensation at different levels of reflectance.

"On the panel of the measuring unit shown in Fig. 1 are the three potentiometer dials and two polarity switches from which values of R_d, a, and b are read. Also there are a balancing rheostat, galvanometer switch, circuit selector, and the instrument control switches. There are normally two of these switches, one for charging rate and one to turn galvanometer lamp off and on. The measurement unit contains a transformer and rectifier to keep the 6-volt automobile battery charged, switches for controlling the galvanometer lamp and for adjusting rate of charge, and cables connecting to 110-volt a.-c. supply, to the galvanometer, and to the exposure unit. To minimize line losses, the cable from the battery is taken directly to the exposure unit. Provision is made to have the charger operate while the lamp is on so that only part of the current required by the 32-candlepower lamp is drawn from the battery. The charger and rectifier are omitted when an electronic voltage regulator is to be used.

"... The instrument gives three numbers for each color measured; R_d or (luminous) reflectance; a which measures redness when plus, zero for gray, greenness when minus, and b which measures yellowness when plus, zero for gray, blueness when minus. (The three scales are visualized in a color solid in which the a and b axes are plotted in a horizontal plane, and the R_d axis is vertical.)

"... As is shown in detailed description of the apparatus mentioned above (*5*), the three potentiometer dials of the new instrument give numbers which relate to the standard I.C.I. specifications of color by the following equations:

$$\begin{aligned} R_d &= 100Y \\ a &= 175f_Y(1.02X - Y) \\ b &= 70f_Y(Y - 0.847Z) \end{aligned} \qquad (1)$$

where

$$f_Y = 0.51(21 + 20Y)/(1 + 20Y)$$

"The tristimulus source-filter-photocell combinations used in the present apparatus are essentially those developed by the writer (Hunter) several years ago (*6*, also see *2*). They provide spectral approximations to the I.C.I. standard observer such that in terms of reflectances measured with the author's multipurpose reflectometer (*7*), the new apparatus gives:

$$\begin{aligned} R_d &= 100G \\ a &= 175f_G(0.80A - G + 0.20B) \\ b &= 70f_G(G - B) \end{aligned} \qquad (2)$$

where

$$f_G = 0.51(21 + 20G)/(1 + 20G)$$

[In equations (2), G is the luminous reflectance, determined with the green filter, selected to be a measure of Y; A is the reflectance determined with the amber-colored filter; B is the reflectance determined with the blue filter, selected to be a measure of $0.847Z$ or $(1/1.1812)Z$. The quantity $(0.80A + 0.20B)$ is intended to be a measure of $1.02X$ or $(1/0.9804)X$. Illuminant C is assumed.]

"In operation, the new apparatus compares unknown specimens with standards of predetermined color characteristics. As was shown in the author's (Hunter's) previous paper on photoelectric colorimetry, the major errors of color measured with photoelectric tristimulus combinations arise from failure of the source-filter-photocell combinations to be spectrally equivalent to the I.C.I. standard observer. Moreover, the spectral properties of these source-filter-photocell combinations vary from one instrument to another, chiefly from variations in the spectral responses of the photocells. Thus the magnitudes of these errors always tend to increase with magnitude of color difference between specimen and standard.

* The statements given in the last two sentences of this paragraph are not consistent with each other. A change in source intensity occasioned by a change in lamp voltage does affect instrument results, because the spectral composition of the light to the comparison photocell is not the same as that of light to the measuring photocells; the statement should indicate that a small change in source intensity does not seriously affect instrument results.

"In the detailed paper (5) it is shown that for the measurement of a large color interval (between white standard and a strong green, blue or red specimen), the error in terms of the fundamental scales defined in equations (1) is likely to total 4 units and the disagreement between one color difference meter and another is likely to total 2.5 units. (The numerical value of a color difference is computed from a formula, quoted in the following paragraph.) For a small color interval between standard and sample of similar color, however, the error and disagreement drop to about 0.2 unit. A color difference of about 0.3 unit is about the smallest visually detectable by a skilled observer working under ideal conditions. Thus with small color intervals, the precision of the instrument is as good or better than that of the human eye trained for the detection of small color differences."

The numerical values of small color differences (intended to be measured in terms of the NBS units) may be calculated from the instrumental dial readings, or from changes in the galvanometer deflection. The difference in color is computed with equation (3):

$$\Delta E = (\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2 \qquad (3)$$

that is, the color difference is the difference between two vectors in the color solid. The quantities a and b have already been defined; ΔL is calculated from the difference between the R_d values by means of the relation, $\Delta L = \Delta R_d(dL/dR_d)$, in which the quantity in parentheses is the variation in lightness per unit change in luminous reflectance. The latter is an arbitrary function and is therefore known; Hunter presents a tabulation of values of dL/dR_d versus R_d. He also describes a geometrical method for obtaining the color difference in accordance with equation (3).

SECTION II. CONSIDERATIONS BASIC TO THE PROGRAM OF INVESTIGATION

If it be taken for granted that one desires only an instrument for the routine control of the color of paper and is willing to forego the analytical advantages of spectrophotometry, he is then primarily concerned with one question about the Hunter Color and Color-Difference Meter: "Is the instrumental indication of a color match valid and sufficiently sensitive and, if a mismatch is indicated, is the direction of the calculated difference accurate?" The first portion of this question is, of course, a special case of the latter part—a perfect match will rarely, if ever, be encountered, so that one is interested in the nature of the mismatch that the instrument indicates. Is the magnitude of the calculated color difference about right and, more important, is the direction of the difference in the color solid about the same as that which would be perceived by a person with normal color vision? If the instrument is defective, it might be expected to match colors in much the manner as a person whose color vision is defective. The tristimulus distribution functions for such a person deviate appreciably from those of the I.C.I. standard observer; if the deviation is great, the person might be classed as an anomalous trichromat. The color matches produced by such persons are rarely acceptable to an observer whose color vision is "normal" and, vice versa, a color match produced by a person with normal color vision will appear to be a mismatch to the deviate. Arguments between two or more experienced color matchers concerning the matching of a submitted sample (where the men are classified as having normal color vision on the basis of the Ishihara and other confusion tests) offer homely evidence that variations within the normal classification are large enough to cause trouble. Our question, then, is a matter of some importance, because poor color control would be the result in numerous cases if the instrument behaved like a "color-blind" person.

Two types of color matches are normally recognized: (1) metameric matches and (2) nonmetameric matches. A metameric color match is good for only one illuminant. For example, the match is metameric if it appears to be good under an artificial illuminant but poor under daylight. The corresponding spectral reflectance curves are not "parallel" in the sense that one color curve can be obtained from the other by multiplying the latter by a constant; rather, one curve "snakes around" the other curve. Accordingly, the tristimulus values for the two colors may be similar for only one spectral energy distribution of illuminant—that is, the illuminant under which the visual matching was achieved. A nonmetameric color match is an idealized match that is good for all illuminants. The color curves for the two colors are identical at all wavelengths. The most extreme metameric matches are obtained when a submitted sample of unknown history is to be matched, whereas color matches tend to be nonmetameric in the normal production of paper, where the furnish of the paper is known and is carefully controlled. However, the commonly held feeling that the color of paper in normal production is held constant in a nonmetameric manner is, unfortunately, not true. The color of each pulp, the quality of the dyestuffs, the color of the filler, and of each material comprising the furnish vary sufficiently to result in metameric matching; the color curve for paper taken from the machine at any given point cuts across the standard curve in one, two, or more points, if the match is as good as possible for the given conditions of operation.

The success or failure, then, of a slightly "color-blind" instrument, in a given application, will depend on the intensity of metamerism in the production of a given run of paper and on the magnitude of the color difference existing between the color of the paper and the color of the reference standard. If the shape and level of the color curve are quite constant (that is, if all the components of the furnish and all of the paper machine variables are closely controlled, so that nonmetameric matching is approached), and if the difference in color between the sample and the reference standard is small, the defective colorimeter will yield accurate color control. If not, unreliable color matching may result. It is obviously impossible generally to draw a line between these cases. The best that can be done in a limited program of investigation is to test the instrument with regard to its performance on several families of colors of known characteristics. On the basis of the results obtained, an appraisal may be made which should help some of the potential users of the instrument to decide whether or not the Color and Color-Difference Meter would be of value to them. The major portion of the experimental program presented herein has been conducted with this goal in mind. In

addition, tests have been made of those instrumental variables which could be measured without serious disassembly of the instrument. The results of the latter tests are presented in the following section; data on the performance of the instrument are given in Section IV.

SECTION III. GENERAL OBSERVATIONS

Sensitivity

The Hunter Color and Color-Difference Meter (hereafter referred to as the HCDM) is equipped with a very sensitive spotlight galvanometer, so that very small changes in illumination of the blocking-layer type photocells can be detected. The performance with regard to sensitivity was checked at several points on each of the three scales, and was found to be very good, as shown by the data presented in Table I.

Table I. Sensitivity of the Instrument

R_d		a		b	
Setting	*Sensitivity, mm./unit*	*Setting*	*Sensitivity, mm./unit*	*Setting*	*Sensitivity, mm./unit*
85.3	13.5	− 1.1	18.0	−32.9	9.0
63.7	13.9	−17.2	15.1	+ 1.8	16.8
50.0	16.3	+11.2	14.5	+12.0	14.6
22.2	14.4	+24.0	15.5	+27.0	14.0
6.7	14.2	+44.0	9.0	+51.8	14.0

It is seen that the least detectable changes are a small fraction of the HCDM approximation to the NBS unit. If the least detectable change is 0.1 mm. (in galvanometer deflection), then, as a rule, the detectable change in *a*, *b*, and R_d would be of the order of 0.007. Therefore, sensitivity, which is a necessary but not sufficient requirement for satisfactory color matching, is excellent. It should not be necessary for the operator of a HCDM to balance the instrument to the least detectable movement of the galvanometer spot—operation is not tedious or "fussy."

Sensitivity to Fluorescent Infrared Radiation

In Report 8, Parts I, II, and III, data concerning the discovery and correction of fluorescent infrared radiation (stimulated by visible light) were presented (*8*). If such radiation can be detected by the receptors of a colorimetric instrument and is not blocked with a suitable filter, appreciable error may result. Although an appreciable response to infrared light is not expected in an instrument having filters and photocells like those employed in the HCDM, it was felt to be desirable to test this rather important point.

Table II. Data on Infrared Response

Specimen	R_d	a	b
Hunter white standard	63.0	−1.1	+1.8
Black velour paper	1.1	...	...
With Wratten No. 87 Filter in Place			
Hunter white standard	0.69	...	...
Black velour paper	0.52	...	...

To perform this test, the Fresnel lens was covered with an opaque sheet containing a central square hole, which was just smaller than a 2-inch square Wratten No. 87 filter. Readings were obtained with, and without, this combination of opaque sheet and filter. The filter blocks visible light, but passes near-infrared radiation freely. The results are presented in Table II. The data presented in Table III show that the result obtained with the Hunter white standard and with the filter in place (Table II) is essentially the zero reading. It is concluded that the effect of any slight response to infrared radiation is quite negligible.

Reflection of Stray Light from Specimen Holder

Although there was not much appearance of stray light on the bottom surface of the specimen holder, it was considered possible that the integrated effect of such light might result in appreciable error. The circular aperture in the holder was found to have a radius of 1.125 inches (3.98 square inches). The influence of stray light was estimated by centrally locating a series of special specimens on the holder. These were pieces of white paper of similar reflectance containing holes of various sizes, ranging from 1.094 to 1.00 inch radius. Thus, the reflecting zones were annuli of width varying from 0.031 to 0.125 inch, with the outer boundary in each case the limiting edge of the specimen aperture. With each illuminated annulus in proper position, a reading was taken of R_d. The results are given in Table IV and are plotted in Fig. 2. In view of the fact that the curve passes through the point for full area at a reading that is very nearly equal to the true zero reading, it is concluded that the effect of stray light is negligible.

Table III. Data on the Determination of the Zero Reading of the R_d Scale

	Specimen	R_d
1.	Room dark, nothing over specimen opening	0.58
2.	Condition 1 and Fresnel lens aperture completely covered with black velour paper	0.52
3.	Condition 2 except now Hunter white standard over specimen opening	0.62
4.	Condition 2 except black velour paper over specimen opening	0.55

Angles of Illumination

The HCDM employs the I.C.I. geometry of illuminating and viewing—that is, the instrument approaches unidirectional illumination at 45° and involves a mean angle of viewing at 0° (perpendicular to the specimen). Although the latter angle could not be accurately estimated, it was believed to be desirable to measure the angles of incidence of the two beams employed in the HCDM. It is to be expected, in most cases, that a variation of the angle of incidence is appreciably more serious than a similar variation of the angle of the accepted rays, where the former is in the neighborhood of 45° and the latter at 90°.

The HCDM utilizes two illuminating beams in the same plane. This plane is parallel to the front of the instrument, and the two beams illuminate the specimen aperture from opposite sides. This arrangement does not constitute an essential variation from the I.C.I. geometry. The angles of illumination were measured in the following manner. The instrument was leveled and so arranged that a beam would illuminate a spot on a wall of tested verticality. Fairly large distances

were chosen to minimize error. The plane of the specimen holder was extended in a line to the wall and, through measurements of the horizontal and vertical distances to the center of the illuminated spot (which was estimated several times by several observers), the angle of incidence was computed. It was estimated conservatively that the uncertainties in the vertical distances to the two spots were not greater than 0.5 inch, which corresponds to an error of 0.7%. (This error will appear to be surprisingly large to some readers; the uncertainty arises in the fact that one is not dealing with a narrow pencil of parallel rays but, rather, with a fairly wide beam in which the intensity distribution is not uniform.) On this basis, the maximum error in the determination of the angle is computed to

Table IV. Data Concerning Effect of Stray Light

R_d, %	Aperture radius, in.	Area exposed, sq. in.
0.52	1 1/8	3.98
0.62	1 3/32	3.76
0.70	1 1/16	3.55
0.89	1 1/32	3.34
1.20	1	3.14

be 0.7 sin 45° cos 45° = 0.35%, or about 0.16°. The angles of the beams proceeding from left to right and from right to left were, respectively:

Left–right: 45.8 ± 0.2°
Right–left: 45.5 ± 0.2°

These angles are felt to be adequately close to 45°, because the use of the instrument does not require high accuracy in the absolute value of the apparent reflectance.

Linearity

Small color differences (from a standard) may be determined fairly directly from the deflections of the galvanometer. Generally, however, the instrumental readings are obtained from the three ten-turn potentiometers. The question of the electrical linearity of the potentiometers suggests itself. The electrical resistance of each potentiometer was determined for a number of settings by isolating each potentiometer electrically and inserting it in a Wheatstone bridge. The data obtained in this way are presented in Table V. In each case, the data given in the third column (under N_{R_d}, N_a, and N_b) are the resistances adjusted to: 100.0 for the R_d setting of 100.0, 80.0 for the *a* setting of 80.0, and 99.0 for the *b* setting of 99.0. The linearity of the R_d potentiometer is seen to be quite good, the largest error being of the order of 0.2 reflectance unit. The results for the *a* and *b* potentiometers are not so favorable, the largest deviations being of the order of 0.7 unit. Where the colors of the specimen and the standard are quite close together, these discrepancies would probably not cause trouble, because the change in error with change of setting is not sharp; otherwise, the errors resulting from the deviations from linearity might be serious.

The linearity of all three scales could not be checked readily under operating conditions, because the circuitry is such that testing with achromatic screens can be done only with the R_d scale. This scale was tested in the following manner. A 1-inch beam of parallel light was directed normally and centrally through the specimen aperture, and the two illuminating beams normally employed in reflectance work were blocked off. A 32-c. p. automotive lamp was used for the auxiliary beam; this lamp was connected in parallel with the lamp in the HCDM, and current to the pair of lamps was furnished with a 6-volt storage battery. With the room darkened, this arrangement could then be used for measuring transmission. Care was exercised to avoid the slight error attributable to small

Table V. Electrical Linearity of the Helipots

R_d Helipot				a Helipot				b Helipot			
R_d Setting	R_1	N_{R_d}	Difference	a Setting	R_1	N_a	Difference	b Setting	R_1	N_b	Difference
100.0	95.9	100.0	0.00	99.5	102.7	98.98	−0.52	99.0	103.5	99.0	0.00
90.0	86.3	89.99	−0.01	99.0	102.1	98.40	−0.60	90.0	94.2	90.10	+0.10
85.0	81.4	84.88	−0.12	90.0	93.1	89.73	−0.27	80.0	83.8	80.15	+0.15
80.0	76.8	80.09	+0.09	80.0	83.0	80.00	0.00	70.0	73.4	70.21	+0.21
75.0	71.9	74.98	−0.02	70.0	72.8	70.16	+0.16	60.0	62.8	60.07	+0.07
70.0	67.1	69.97	−0.03	60.0	62.4	60.14	+0.14	59.0	61.7	59.02	+0.02
65.0	62.3	64.97	−0.03	59.0	61.4	59.18	+0.18	58.0	60.7	58.06	+0.06
60.0	57.6	60.06	+0.06	58.0	60.4	58.21	+0.21	57.0	59.7	57.10	+0.10
59.0	56.6	59.02	+0.02	57.0	59.3	57.15	+0.15	56.0	58.6	56.05	+0.05
58.0	55.8	58.19	+0.19	56.0	58.4	56.28	+0.28	55.0	57.6	55.09	+0.09
57.0	54.6	56.94	−0.06	55.0	57.2	55.13	+0.13	54.0	56.6	54.14	+0.14
56.0	53.7	56.00	0.00	54.0	56.2	54.16	+0.16	53.0	55.5	53.08	+0.08
55.0	52.8	55.06	+0.06	53.0	55.2	53.20	+0.20	52.0	54.4	52.03	+0.03
54.0	51.8	54.02	+0.02	52.0	54.2	52.24	+0.24	51.0	53.4	51.08	+0.08
53.0	50.9	53.08	+0.08	51.0	53.1	51.18	+0.18	50.0	52.3	50.02	+0.02
52.0	49.8	51.93	−0.07	50.0	52.1	50.21	+0.21	40.0	41.9	40.08	+0.08
51.0	48.9	50.99	−0.01	40.0	41.8	40.29	+0.29	30.0	31.4	30.03	+0.03
50.0	47.9	49.95	−0.05	30.0	31.5	30.36	+0.36	20.0	21.1	20.18	+0.18
40.0	38.3	39.94	−0.06	20.0	21.3	20.53	+0.53	10.0	10.8	10.33	+0.33
30.0	28.9	30.14	+0.14	10.0	11.1	10.70	+0.70	9.0	9.8	9.37	+0.37
20.0	19.4	20.23	+0.23	9.0	10.1	9.73	+0.73	8.0	8.8	8.42	+0.42
10.0	9.8	10.22	+0.22	8.0	9.0	8.67	+0.67	7.0	7.8	7.46	+0.46
9.0	8.8	9.18	+0.18	7.0	7.9	7.61	+0.61	6.0	6.8	6.50	+0.50
5.0	5.0	5.21	+0.21	6.0	6.9	6.65	+0.65	5.0	5.8	5.55	+0.55
1.0	1.0	1.04	+0.04	5.0	5.8	5.59	+0.59	4.0	4.8	4.59	+0.59
0.5	0.6	0.63	+0.13	4.0	4.9	4.72	+0.72	3.0	3.8	3.63	+0.63
0.0	0.16	0.17	+0.17	3.0	3.9	3.76	+0.76	2.0	2.8	2.68	+0.68
				2.0	2.8	2.70	+0.70	1.0	1.8	1.72	+0.72
				1.0	1.8	1.73	+0.73	0.0	0.7	0.67	+0.67
				0.0	0.6	0.58	+0.58				

Normalization factor = $\frac{100.0}{95.9}$ = 1.0428 Normalization factor = $\frac{80.0}{83.0}$ = 0.9638 Normalization factor = $\frac{99.0}{103.5}$ = 0.9565

movement of the light beam relative to the Fresnel lens and integrating cavity. A series of screens were mildly blackened with carbon soot. The transmission of each was carefully determined with the G.E. recording spectrophotometer (hereafter referred to as the GERS), and the tested areas were carefully noted. These areas were then tested with the HCDM by inserting the screens one by one in the auxiliary light

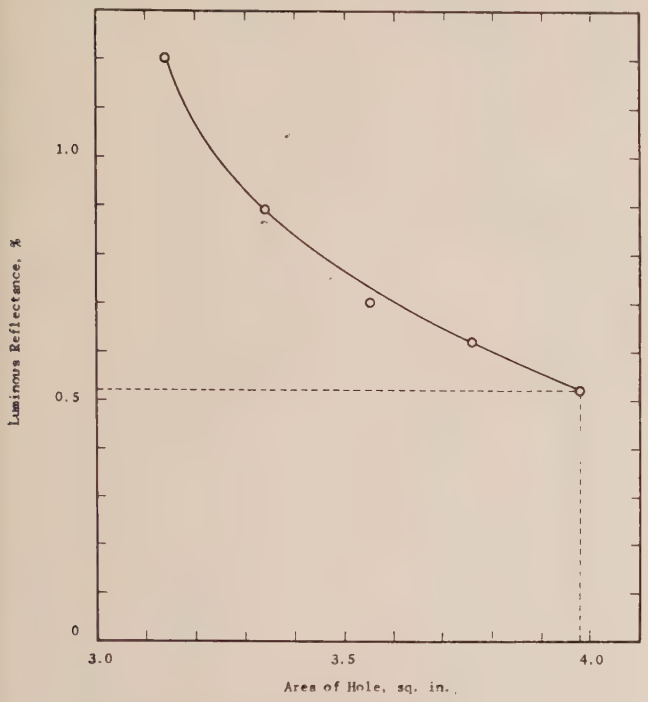

Fig. 2. Test for stray light. Reflectance versus area of a paper annulus bounded by a hole in the paper and the sample aperture

beam, centering the beam on the noted areas. Immediately prior to each test, the instrument was balanced with the R_d scale at 100.0, and with nothing in the light beam. The results, presented in Table VI, show that the two instruments agreed rather well. The discrepancy obtained with the No. 3 screen is inconsistent with the other data—especially with the closely neighboring result for screen No. 4. These data, taken together with those of Table V for R_d, assure one that

Table VI. Linearity of the Rd Scale (in Operation)

Screen no.	*Transmission (GERS, %)*	*Rd Reading, %*	*Difference*
1	22.7	22.6	−0.1
2	61.7	61.8	+0.1
3	42.7	43.2	+0.5
4	42.4	42.6	+0.2

the operating linearity of the R_d scale is quite good. However, the results for the potentiometers for the *a* and *b* scales (Table V) lead necessarily to the conclusion that these scales are nonlinear in operation, at least to the extent shown in Table V.

Summary and Conclusions

Examination of the variables that can be tested directly shows that the sensitivity of the HCDM is very good; the error attributable to fluorescent infrared radiation is completely negligible; the error caused by stray light is absent; the angles of the illuminating beams do not appear to be accurately 45°, but the errors are small and it is believed that the influence of these errors is negligible when the color difference between the specimen and the standard is small; the operating linearity of the R_d scale is very good, but deviations from electrical linearity of the *a* and *b* potentiometers could cause appreciable error when the color difference between the specimen and the standard is not small. The factors discussed thus far are fairly rudimentary. In the next section the performance of the instrument as a color matcher is discussed.

SECTION IV. PERFORMANCE OF THE INSTRUMENT IN COLOR MATCHING

As discussed in Section II, the performance of the HCDM can be tested through the use of families of colors which have been studied spectrophotometrically and for which the colorimetric characteristics have been

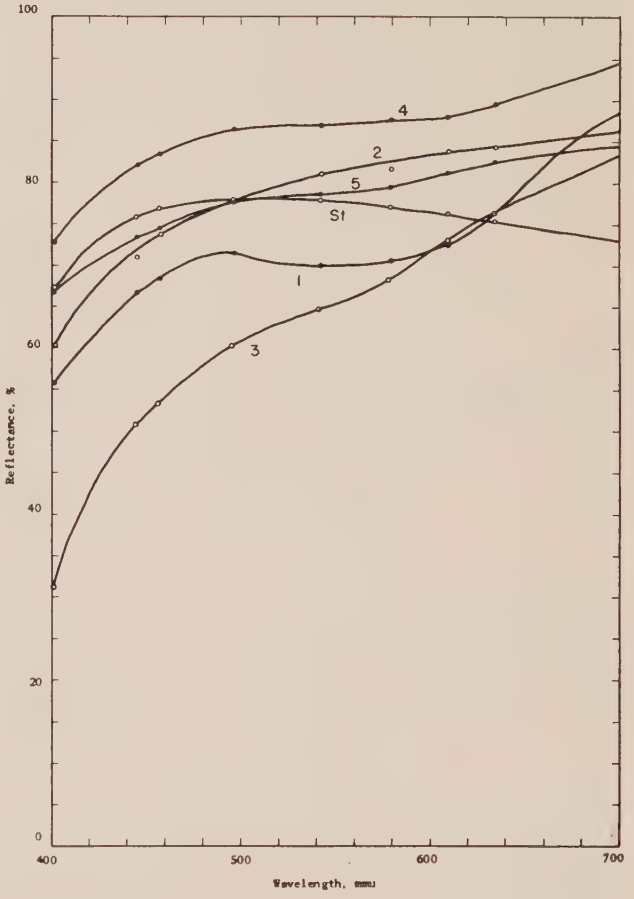

Fig. 3. Spectral reflectance curves for a white enamel standard (ST) and five papers: (1) sulphite bond paper; (2) facial tissue; (3) book paper; (4) bond paper (TiO_2 filler); (5) coated paper (supercalendered)

calculated. In this work we shall be primarily concerned with the *reliability of indication of the HCDM regarding the magnitude and direction of a color difference.*

"White" Paper

Our first concern was with "white" papers. It seems likely that a user of the HCDM in the paper industry would tend to employ almost any reasonably stable

white standard for the control of the color of any given white paper. Although the gamut of color covered by commercial white papers is fairly large, there would undoubtedly be a strong tendency for a technical man to regard the color difference between a white enamel or

Table VII. Tristimulus and Calculated Hunter Values for White Paper Series (GERM)

Specimen	X	Y	Z	*Rd*	a	b
White enamel standard	0.7490	0.7731	0.9002	77.3	−1.8	+ 0.8
Bond paper (TiO_2 filler)	0.8542	0.8739	0.9784	87.4	−0.5	+ 3.4
Coated paper (super-calendered)	0.7769	0.7928	0.8768	79.3	−0.1	+ 3.9
Sulphite bond paper	0.7022	0.7124	0.7977	71.2	+0.8	+ 3.0
Book paper	0.6594	0.6688	0.6217	66.9	+0.8	+12.1
Facial tissue	0.7953	0.8164	0.8648	81.6	−1.0	+ 6.4

porcelain tile standard and his white paper to be relatively small. Accordingly, it seemed to be of interest to compare calculated and observed values of R_d, *a*, and *b* for a series of white papers, using a single white enamel standard. An accurate spectrophotometer incorporating the I.C.I. 45°, 90° geometry of illuminating and

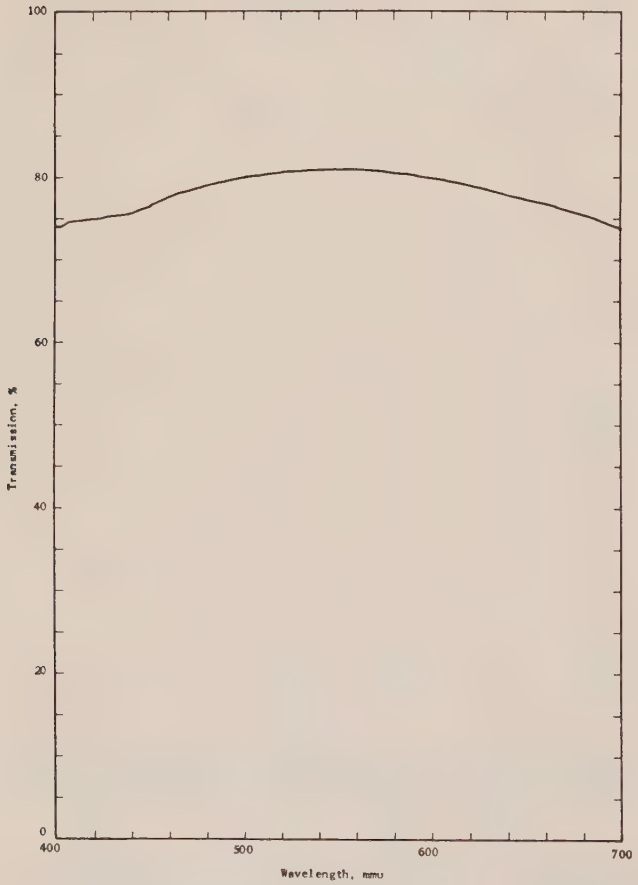

Fig. 4. Spectral transmission curve for the combination glass standard

viewing was not available and, hence, spectral reflectance curves for the standard and for the white papers were determined with the G.E. reflection meter (hereafter referred to as the GERM), guided by the GERS. The GERM is an abridged spectrophotometer equipped with nine "monochromatic" filters, for each of which the effective wavelength is known, and its geometry of illuminating and viewing is similar to that of

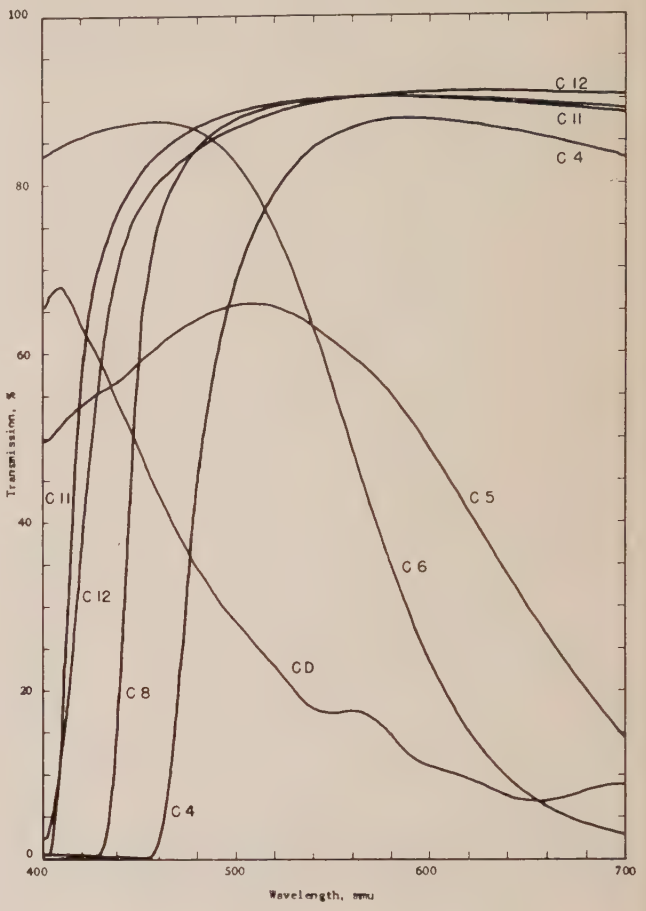

Fig. 5. Spectral transmission curves for seven Corning glass filters

the HCDM. Spectral errors are least in abridged spectrophotometers when they are employed to determine the color of white or nearly white surfaces. In our work with the GERM, the curves were drawn through the

Table VIII. Experimental Hunter Values for the White Paper Series

Specimen	*Rd*	a	b
White enamel standard	77.3	−1.8	+ 0.8
Bond paper (TiO_2 filler)	87.2	−0.6	+ 4.9
Standard	77.3	−1.8	+ 0.7
Coated paper (supercalendered)	79.8	−0.1	+ 5.8
Standard	77.2	−1.9	+ 0.8
Sulphite bond paper	72.5	+1.3	+ 3.9
Standard	77.3	−1.8	+ 0.8
Book paper	68.5	+1.5	+15.6
Standard	77.3	−1.8	+ 0.8
Facial tissue	83.3	−0.7	+11.6
Standard	77.3	−1.9	+ 0.9

points with the help of curves for the same specimens, recorded by the GERS. The spectral reflectance curves so determined are reproduced in Fig. 3. The ultimate standard of reflectance was MgO.

Tristimulus values for the white enamel standard and the papers were obtained by means of the I.P.C. mechanical integrator (*9*). The Hunter quantities R_e, *a*, and *b* were calculated by means of equations (1) for

the enamel standard and the papers. The results are given in Table VII. The observed Hunter values for this series are given in Table VIII, and the calculated and observed values are compared in Table IX.

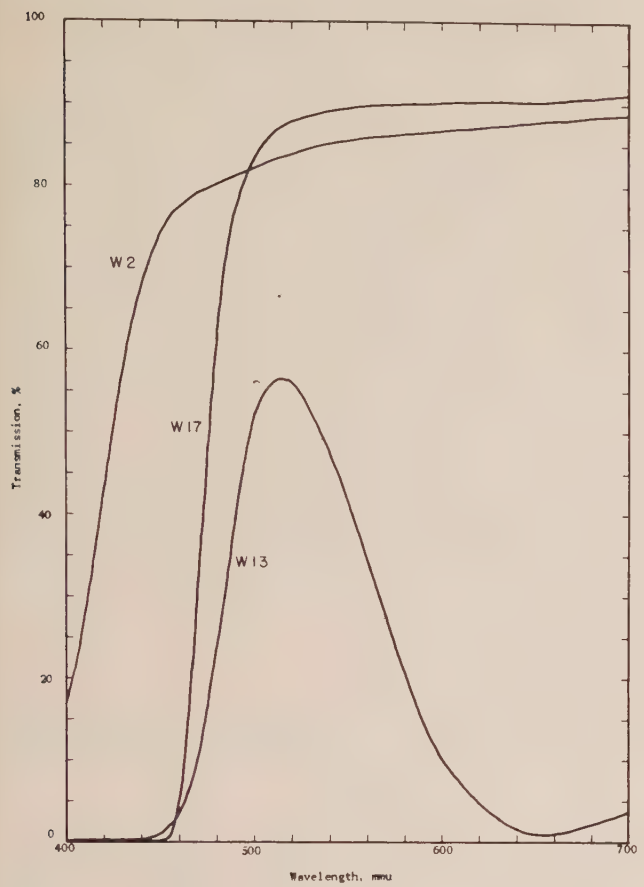

Fig. 6. Spectral transmission curves for three Wratten filters

In each column of Table IX, the observed Hunter result is given first, followed by the calculated value. The differences given in the associated columns are obtained by subtracting the calculated values from the observed data. The data for R_d are the most familiar, because R_d is intended to be the per cent luminous reflectance ($100Y$). As one might expect from the results presented in Section III, the agreement for this value is fair. It is believed that the discrepancies are attributable to the "translucency effect" (*8*), and are not necessarily the result of one instrument being erroneous and the other correct. This effect is known to be large in a material like facial tissue. On comparing the results for the bond paper and the facial tissue, it will be noticed that the reflectances are not far apart, yet the differences are, respectively, -0.2% and $+1.7\%$. The discrepancy can scarcely be the result of a photometric error in either instrument and, if it is to be attributed to spectral error, it would be necessary to assume that the effective wavelength for the Hunter response with the green filter is too great by about 20 mmu, which seems improbable in view of data to be presented later. Accordingly, the discrepancy is tentatively ascribed to differences between the geometries of the instruments which, among other things, would cause the translucency effect to be different in the two instruments.

The calculated and observed values of a are seen to be in fair agreement, the largest difference being less than one NBS unit. However, better agreement should have been obtained for the b values (last pair of rows of Table IX) than that actually found. Four out of the five differences are substantially greater than one NBS unit, and the largest discrepancy is estimated to be about *15 least perceptible color steps*. It is not expected that this sort of error should result from the translucency effect but, if this be considered debatable, we note that the discrepancy for the book paper, for which the translucency effect is known to be almost negligible, is roughly 10 least perceptible color steps—a very large visual difference. In order that the underlying reasons for variations in b might be investigated, we may first assume that the constants of the circuit are correct and that the responses of the photocells are properly adjusted, and then inquire into the sort of errors in reflectance that would be needed to explain any given variation in b—for example, +3.5 units. On differentiating the third equation of equations (2), we find, for small variations,

$$\delta b = 70[f_G - 204\ (G - B)/(1 + 20G)^2]\ \delta G - 70 f_G \delta B \qquad (4)$$

in which δG and δB may be thought of as errors in, respectively, the green reflectance and the blue reflectance. A numerical example will clearly show the connection between δB and errors in reflectance. Let us

Table IX. Summary of Calculated and Experimental Hunter Values for White Specimens[a]

Specimen	*Rd*	*Rd Difference*	a	a *Difference*	b	b *Difference*
White enamel standard	77.3		−1.8		+ 0.8	
Bond paper (TiO_2 filler)$_H$	87.2		−0.6		+ 4.9	
		−0.2		−0.1		+1.5
Bond paper (TiO_2 filler)$_C$	87.4		−0.5		+ 3.4	
Coated paper (supercalendered)$_H$	79.8		−0.1		+ 5.8	
		+0.5		0.0		+1.9
Coated paper (supercalendered)$_C$	79.3		−0.1		+ 3.9	
Sulphite bond paper$_H$	72.5		+1.3		+ 3.9	
		+1.3		+0.5		+0.9
Sulphite bond paper$_C$	71.2		+0.8		+ 3.0	
Book paper$_H$	68.5		+1.5		+15.6	
		+1.6		+0.7		+3.5
Book paper$_C$	66.9		+0.8		+12.1	
Facial tissue$_H$	83.3		−0.7		+11.6	
		+1.7		+0.3		+5.2
Facial tissue$_C$	81.6		−1.0		+ 6.4	

[a] The subscript H indicates the experimental Hunter values and the subscript C indicates the calculated Hunter values, based on data obtained with the GERM.

assume a white paper, for which $G = 0.70$ and $B = 0.65$. If error exists only in B, then the error in b for 0.01 decrease in B is found to be $+0.83$. If error exists only in G, then the error in b for 0.01 increase in G is found to be $+0.81$. It appears from data already discussed

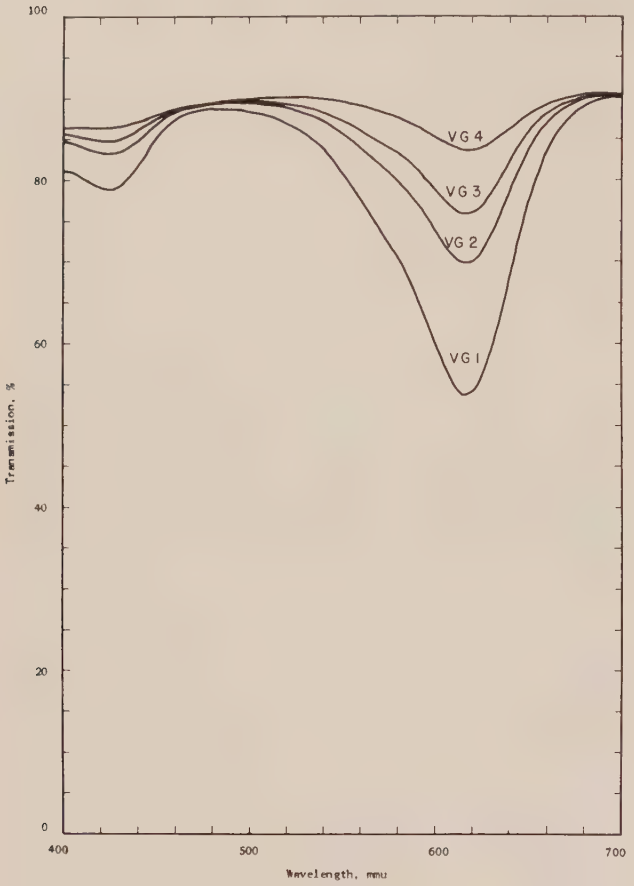

Fig. 7. Spectral transmission curves for four solutions of Victoria green

that we cannot expect an error in G by more than about 0.015, which would account for a variation in b of about $+1.2$. If we assume that the errors in G and B combine additively, then, to have an error in b of $+3.5$, the error caused by discrepancy in B would be $3.5-1.2 = 2.3$ units. Finally, the error in B would have to be $0.01(2.3/0.84) = 0.027 = 2.7\%$ reflectance units. If the error in G were in a direction opposite to that assumed, this computed error in B would be substantially greater

For a material having a color curve like that for the book paper, an error in B of the order of 3% could be caused by incorrect fitting of the spectral response of the instrument to the I.C.I. function for $E_c z$. The corresponding function for the instrument is $E_A TS$, where E_A is the spectral energy distribution for the light (possibly a good approximation to that of I.C.I. illuminant A), T is the spectral transmission of the optical system (mainly influenced by the blue filter), and S is the spectral sensitivity of the b photocell. A possible reason for the apparently erroneously high values of b could be found in a shift to shorter wavelengths of the spectral response of the instrument; if the centroid or effective wavelength of the instrument function $E_A TS$ were too small by 14 mmu, an error of about 3% would be produced in B in the testing of a material like the book paper. This discussion, which was developed to help us relate a discrepancy in b to the error in blue reflectance, could be extended in an obvious manner

Table X. Tristimulus and Calculated Hunter Values for Glass Filters

Filter	X	Y	Z	*Rd*	a	b
CGS	0.7816	0.8079	0.9135	80.8	− 2.1	+ 2.6
C12	0.8513	0.8965	0.8734	89.6	− 5.2	+11.5
C11	0.8583	0.8977	0.9392	89.8	− 4.1	+ 7.5
C4	0.6956	0.8164	0.1546	81.6	−20.6	+52.7
C8	0.7985	0.8924	0.6218	89.2	−14.3	+26.9
C5	0.4995	0.5720	0.7087	57.2	−14.6	− 2.6
C6	0.4020	0.5010	1.0259	50.1	−22.9	−37.0
CD	0.1961	0.1804	0.5535	18.0	+ 9.3	−55.0
W2	0.8156	0.8528	0.8450	85.3	− 3.9	+10.3
W13	0.1410	0.3161	0.1014	31.6	−57.4	+30.7
W17	0.7260	0.8680	0.2144	86.8	−23.8	+51.2

CGS refers to combination glass standard. CD refers to Corning daylight. C refers to Corning filter. W refers to Wratten filter.

to the analysis of errors in a. The foregoing considerations were based on the assumption that there are no errors in the circuit or in the adjustments of the photocell responses. Such errors could, of course, combine addi-

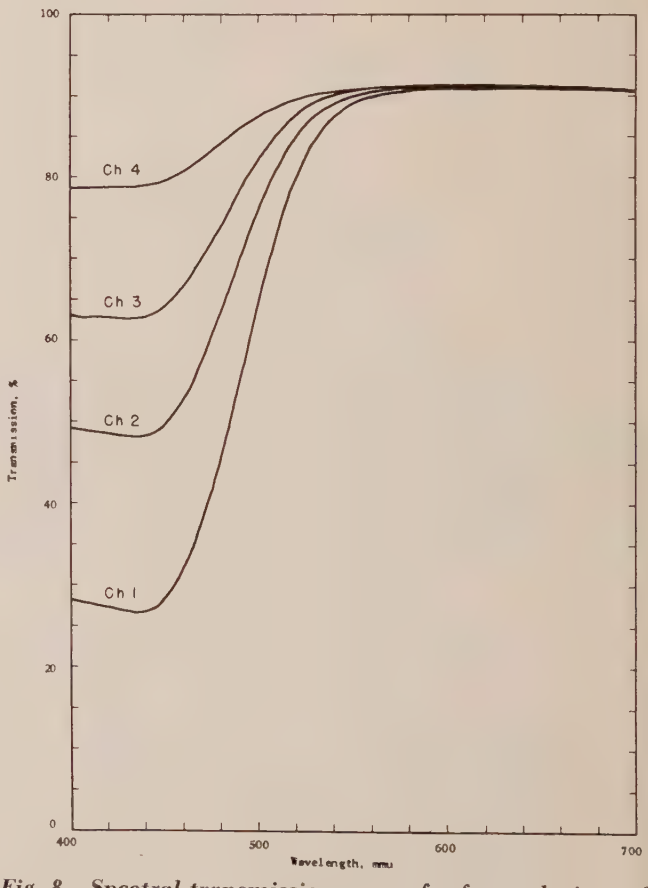

Fig. 8. Spectral transmission curves for four solutions of Chrysoidine

tively with the spectral errors, in which case the discrepancy in the centroid wavelength could be smaller. In any case, the apparent errors in b are rather large. They could be minimized by employing a white standard for a given paper, for which the spectral reflectance

curve (determined with 45°, 90° geometry) is nearly the same as that of the paper. It is evidently not sufficient that the white paper and the white standard have similar values of R_d, a, and b.

Elimination of Geometrical Errors in the Study of Spectral Factors

Accurate colorimetric determinations may be made with the GERS. However, accurate comparisons of the results obtained with the HCDM with calculations based on GERS data cannot be had with reflecting substances because of the differences between the geometries of illuminating and viewing employed in the GERS and in Hunter's instrument. This difficulty can be avoided in a study of the spectral factors of the HCDM by arranging this instrument, as described in Section III, to measure transmission.

In the first series of tests made with this arrangement, a transmission standard was made with a combination of glass plates for which the computed a and b values were each greater than 1.00. According to Hunter, readings from the potentiometers below 1.00 are unreliable, and he describes a special procedure for materials for which a or b is less than 1.00. Were it not for this fact, the reference standard (for setting the

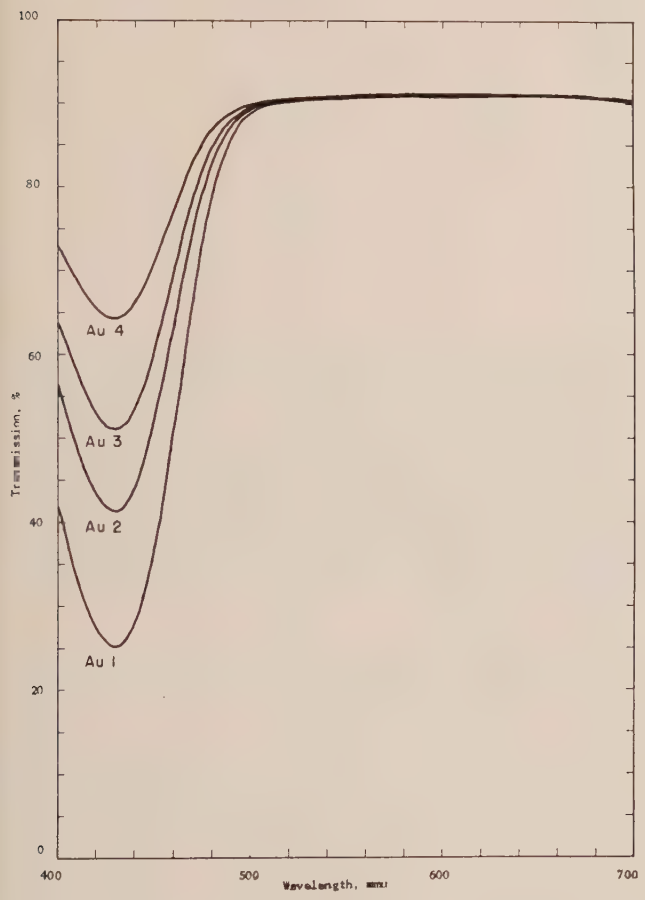

Fig. 9. Spectral transmission curves for four solutions of Auramine

HCDM) would have been just air, for which $R_d = 100.0$, $a = 0$, and $b = 0$. The spectral transmission curves were determined with the GERS for the combination glass standard, seven Corning glass standards, and three Wratten filters. These curves are reproduced in Figs. 4, 5, and 6. Integrations were made to obtain the tristimulus values X, Y, and Z, and the Hunter quantities R_d, a, and b were computed by means of equations (1). These data are presented in Table X.

The HCDM was standardized by placing the glass

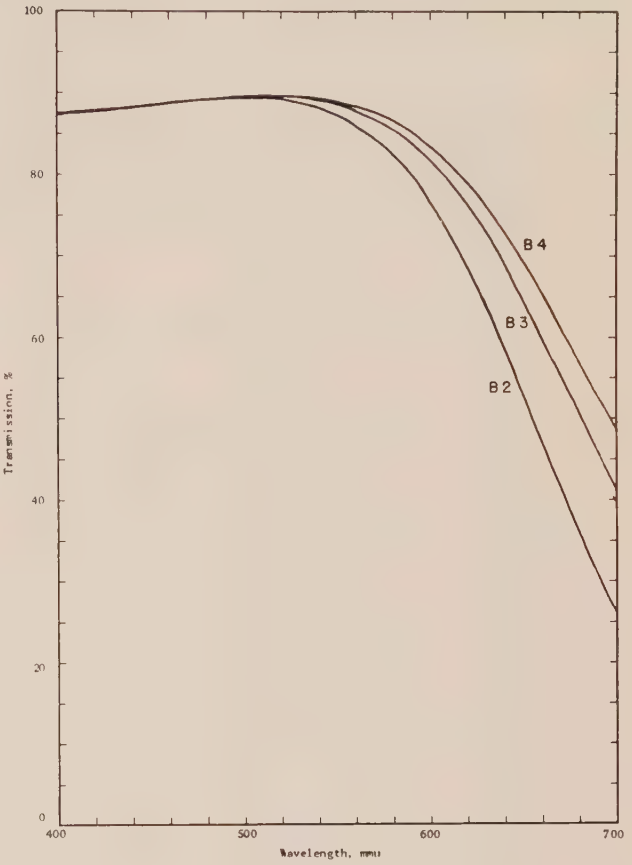

Fig. 10. Spectral transmission curves for three solutions of copper sulphate

standard in the beam and setting the instrument at the calculated values for R_d, a, and b. The readings were then obtained for one of the ten filters; the instrument was carefully standardized immediately prior to the taking of measurements on each filter. The observed data, designated with an H, together with the calculated values, are presented in Table XI. As observed in earlier tests, fairly good agreement was found between the two sets of R_d values. It is of interest to note, however, that the discrepancy is negative when the slope of the spectral transmission curve is positive (filters C12, C11, C4, C8, W2, and W17) in the region of the centroid wavelength for R_d—i.e., near the middle of the spectrum—and positive when the slope is negative in this region (filters C5, C6, CD, and W13). This is quite clear evidence that the centroid wavelength is too small. However, the discrepancies are not large, and the wavelength error is probably not greater than about 2 mmu.

According to Hunter, the HCDM is not recommended for use when the spectral characteristics of the standard and specimen are not similar. It was felt to be of interest, however, in this study of his instrument, to explore the magnitudes of the discrepancies when a large difference existed between the standard and the specimen. The results obtained should enable the reader to

decide how large or small the difference should be in possible application of the instrument; also, an examination of the large discrepancies might well aid in bringing the sources of error to light and thereby suggest improvements in accuracy.

Examination of the data for a and b reveals that the discrepancies for a varied from -5.3 to $+5.7$ units, a spread of 11 units, whereas those for b varied from -10.1 to $+19.3$ units, a spread of roughly 29 units. Again, it is noted that the greater errors (in the case of the particular instrument studied) are in the b scale. Even though the differences between the spectral transmission curves of the standard and specimens are large, it is felt that these discrepancies are unduly large. Strong positive errors are noted for b, when the slope of the curve is great and positive in the region of 450 mmu (filters C4, C8, and W17) and a strong negative error is found when the slope is large and negative in this region (filter CD). This is in agreement with the earlier conclusion that the centroid wavelength for the B reflectance (in the blue portion of the spectrum) is too small.

Filter CD may be used to estimate fairly closely the apparent error in centroid wavelength for the blue reflectance B. The transmission curve for this filter has a small curvature throughout the blue region. Applying equation (4) with the value from Table XI of -10.1 for the error in b, and neglecting the error in G (or R_d), it is found that the error in B for this filter is $+0.053$ or 5.3% reflectance unit. From Fig. 5, it is found that the error in the centroid wavelength is -10 mmu—that is, the effective wavelength is too short. It will be recalled that the estimate made earlier on the basis of the less exact reflectance data was 14 mmu toward the shorter wavelength.

The somewhat smaller errors in the a scale are more difficult to associate with a wavelength error, and it is suggested that they may be more importantly connected with either a circuit error or an error in adjustment of the response of the a photocell.

Table XI. Summary of Calculated and Experimental Hunter Values for Filters

Filter	*Rd*	*Rd Difference*	a	a *Difference*	b	b *Difference*
Combination glass standard	80.8		− 2.1		+ 2.6	
C12 H[a]	89.1		− 3.7		+16.6	
		−0.5		+1.5		+ 5.1
C12 C[b]	89.6		− 5.2		+11.5	
C11 H	88.8		− 2.7		+10.1	
		−1.0		+1.4		+ 2.6
C11 C	89.8		− 4.1		+ 7.5	
C4 H	80.7		−18.3		+72.0	
		−0.9		+2.3		+19.3
C4 C	81.6		−20.6		+52.7	
C8 H	88.6		−10.5		+37.1	
		−0.6		+3.8		+10.2
C8 C	89.2		−14.3		+26.9	
C5 H	57.8		−15.4		− 2.4	
		+0.6		−0.8		+ 0.2
C5 C	57.2		−14.6		− 2.6	
C6 H	51.7		−24.2		−45.8	
		+1.6		−1.3		− 8.8
C6 C	50.1		−22.9		−37.0	
CD H	18.4		+ 4.0		−65.1	
		+0.4		−5.3		−10.1
CD C	18.0		+ 9.3		−55.0	
W2 H	85.2		− 2.5		+14.6	
		−0.1		+1.4		+ 4.3
W2 C	85.3		− 3.9		+10.3	
W17 H	86.4		−19.8		+69.9	
		−0.4		+4.0		+18.7
W17 C	86.8		−23.8		+51.2	
W13 H	32.6		−51.7		+39.4	
		+1.0		+5.7		+ 8.7
W13 C	31.6		−57.4		+30.7	

[a] H = Observed on the HCDM.
[b] C = Calculated from the GERS data.

Table XII. Comparison of Calculated and Observed Data for Yellow Filters

Filter	*Rd*	*Rd Difference*	a	a *Difference*	b	b *Difference*
C12 (standard)	89.6		− 4.8		+12.0	
C11 H	89.3		− 3.8		+ 5.2	
		−0.5		+0.3		− 2.3
C11 C	89.8		− 4.1		+ 7.5	
C4 H	80.8		−19.0		+69.5	
		−0.8		+0.4		+16.8
C4 C	81.6		−20.6		+52.7	
C8 H	89.2		−11.6		+33.1	
		0.0		+2.7		+ 6.2
C8 C	89.2		−14.3		+26.9	

A special series of tests was made with the yellow filters C8, C4, C11, and C12. This test was made in simulation of a situation in which one wishes to control the color of deeply dyed yellow paper. One of the series (filter C12) was taken as standard, and it is reasonable to suppose that one is here concerned with standards

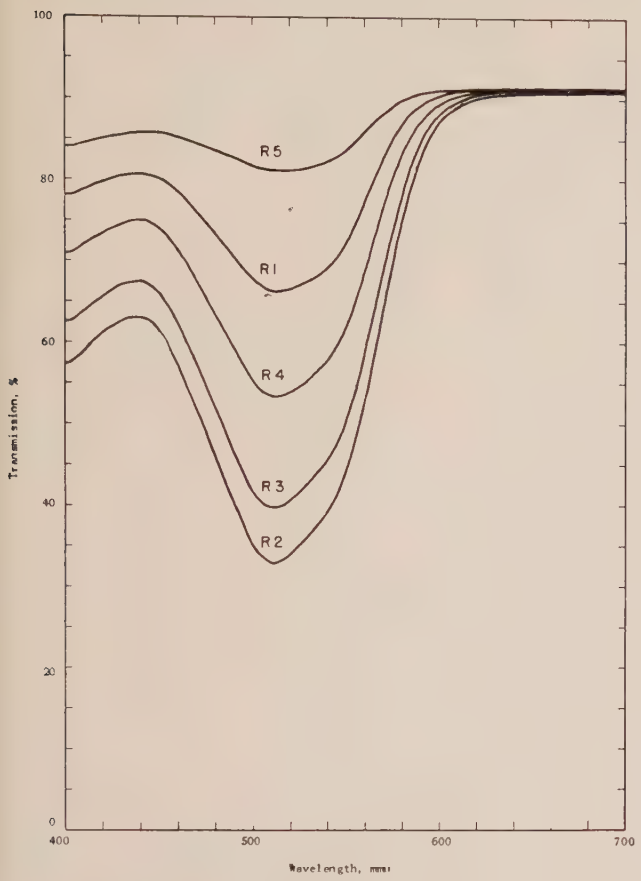

Fig. 11. Spectral transmission curves for five solutions of Fast Red 8BL

and specimens of similar spectrophotometric curves; admittedly, the differences are larger than would probably be considered advisable, but it seems probable that users of the HCDM would employ color standards no less dissimilar from the specimens. The calculated

Table XIII. Approximate Concentration of Dye Solutions

Name		*Concentration, mg./ml., of family members* 1	2	3	4	5
Victoria green	VG	0.002	0.001	0.0006	0.0003	
Chrysoidine GN	Ch	0.010	0.005	0.003	0.001	
Auramine	Au	0.005	0.003	0.002	0.001	
Fast red 8BL	R	0.003	0.010	0.008	0.005	0.001
Copper sulphate (1% H_2SO_4)	B	...	8	5	4	

and observed values for R_d, a, and b are compared in Table XII. It will be noticed that four of the nine differences are objectionably large. The discrepancy of +16.8 for b (filter C4) is equivalent to roughly 50 least perceptible color steps. However, the curves for filters C12 (the standard) and C4 are farther apart than might be considered advisable, so that attention is directed to the two curves that are quite close together and are similar in form (filters C11 and C12). In this case, the discrepancy is 2.3 units, which is large because it corresponds to several least perceptible color steps, and even to more than two of the tolerances that have been arbitrarily set for "commercial matches."

A series of tests were made with nonmetameric colors, obtained by varying the concentrations of dyes in solutions. Five families of colors were prepared as shown in Table XIII. Spectral transmission curves were obtained with the GERS and integrations were made to obtain the tristimulus values. The spectral transmission curves are reproduced in Figs. 7–11, and the tristimulus values and calculated Hunter quantities are given in Table XIV. In measuring the color of each

Table XIV. Tristimulus and Calculated Hunter Values for the Colored Solutions

Solution	X	Y	Z	*Rd*	a	b
VG 1	0.6970	0.7661	1.0036	76.6	−11.0	− 6.7
VG 2	0.7846	0.8322	1.0283	83.2	− 6.1	− 3.0
VG 3	0.8164	0.8550	1.0371	85.5	− 4.2	− 1.8
VG 4	0.8500	0.8814	1.0521	88.1	− 2.7	− 0.7
Ch 1	0.7716	0.8427	0.3995	84.3	−10.5	+38.2
Ch 2	0.8160	0.8725	0.6388	87.2	− 7.5	+24.7
Ch 3	0.8469	0.8927	0.7944	89.3	− 5.3	+12.1
Ch 4	0.8766	0.9057	0.9577	90.6	− 2.1	+ 6.9
Au 1	0.7998	0.8963	0.5686	89.6	−14.8	+30.4
Au 2	0.8259	0.9012	0.7090	90.1	−10.8	+22.0
Au 3	0.8383	0.9016	0.7834	90.2	− 8.5	+17.4
Au 4	0.8580	0.9061	0.8858	90.6	− 5.6	+11.4
R 1	0.8336	0.7883	0.9137	78.8	+12.1	+ 1.1
R 2	0.7183	0.5860	0.6643	58.6	+33.7	+ 2.1
R 3	0.7487	0.6288	0.7242	62.9	+29.8	+ 1.4
R 4	0.7956	0.7159	0.8331	71.6	+19.7	+ 0.8
R 5	0.8703	0.8635	1.0025	86.4	+ 4.5	+ 1.1
B 2	0.7716	0.8350	1.0504	83.5	− 9.1	− 4.2
B 3	0.8122	0.8609	1.0506	86.1	− 7.7	− 1.5
B 4	0.8265	0.8994	1.0508	86.9	− 4.9	− 1.5

solution, the HCDM was first standardized with the combination glass standard, and then with a designated member of the given family of colors. The results are presented in Table XV. In this tabulation, the subscript c indicates the calculated value, the subscript g indicates the observed value when a designated member of the family of colors was used to standardize the instrument. The differences given in the tabulation are only for the comparisons of observed and calculated results when the instrument was standardized with one of the dye solutions in a nonmetameric family. In general, the agreement is not good—especially, again, in the case of the b values, where some of the discrepancies are quite large. In general, fairly good agreement was obtained between the calculated and observed values of R_d and a. As one might expect, the discrepancies are smaller for those members of the families which must closely approach the spectral characteristics of the colored standards.

Measurement of Color Differences in Two Nonmetameric Series of Papers

Although the geometries of illumination and viewing of the GERS and HCDM are different, it was felt to be of interest to establish the color *differences* for two series of nonmetameric colored papers with the GERS and to compare the calculated Hunter quantities with

those observed with the HCDM. The curves for a series of five pink papers and for a series of five green papers are given in Figs. 12 and 13. It will be noticed that the curves in each family are similar in form and that the smaller differences are perhaps of the same order as those encountered in commercial production. The least strongly colored paper in each family (P1 and Gr1) was taken as the standard. The tristimulus values and the calculated values of R_d, a, and b are presented in Table XVI, and the calculated and observed results are compared in Table XVII.

Very good agreement was obtained for the pink series, the largest discrepancy being of the order of a least perceptible color difference. Depending upon the requirements, the errors obtained with the green series might, or might not, be judged serious; all are greater

Table XV. Summary of Calculated and Experimental Hunter Values for the Colored Solutions

Solution	*Rd*	*Rd Difference*	a	a *Difference*	b	b *Difference*
VG 1_c[a]	76.6		−11.0		− 6.7	
VG 1_g	77.6		−10.4		− 9.3	
VG 2_H	83.1		− 6.1		− 1.1	
		−0.1		0.0		+ 1.9
VG 2_c	83.2		− 6.1		− 3.0	
VG 2_g	83.4		− 6.1		− 4.1	
VG 3_H	85.1		− 5.3		− 0.1	
		−0.4		−1.1		+ 1.7
VG 3_c	85.5		− 4.2		− 1.8	
VG 3_g	85.7		− 4.3		− 2.5	
VG 4_H	87.9		− 2.9		+ 2.0	
		−0.2		−0.2		+ 2.7
VG 4_c	88.1		− 2.7		− 0.7	
VG 4_g	88.2		− 2.2		− 0.5	
Ch 1_c[a]	84.3		−10.5		+38.2	
Ch 1_g	83.9		−10.7		+52.4	
Ch 2_H	87.4		− 7.1		+15.3	
		+0.2		+0.4		− 9.4
Ch 2_c	87.2		− 7.5		+24.7	
Ch 2_g	86.8		− 7.6		+33.8	
Ch 3_H	89.1		− 4.7		+ 1.3	
		−0.2		+0.6		−10.8
Ch 3_c	89.3		− 5.3		+12.1	
Ch 3_g	88.9		− 5.0		+21.9	
Ch 4_H	90.6		− 1.7		−14.1	
		0.0		+0.4		−21.0
Ch 4_c	90.6		− 2.1		+ 6.9	
Ch 4_g	90.5		− 2.0		+ 9.0	
Au 1_c[a]	89.6		−14.8		+30.4	
Au 1_g	89.6		−12.5		+41.6	
Au 2_H	90.4		−11.2		+17.4	
		+0.3		−0.4		− 4.6
Au 2_c	90.1		−10.8		+22.0	
Au 2_g	90.2		− 8.8		+29.9	
Au 3_H	90.6		− 9.2		+10.2	
		+0.4		−0.7		− 7.2
Au 3_c	90.2		− 8.5		+17.4	
Au 3_g	90.6		− 6.9		+23.5	
Au 4_H	90.9		− 6.8		+ 1.1	
		+0.3		−1.2		−10.3
Au 4_c	90.6		− 5.6		+11.4	
Au 4_g	90.8		− 4.5		+15.2	
B 2_c[a]	83.5		− 9.1		− 4.2	
B 2_g	84.2		−11.2		− 5.2	
B 3_H	85.9		− 5.5		− 1.6	
		−0.2		+2.2		− 0.1
B 3_c	86.1		− 7.7		− 1.5	
B 3_g	86.5		− 7.8		− 2.8	
B 4_H	86.8		− 4.0		− 1.0	
		−0.1		+0.9		+ 0.5
B 4_c	86.9		− 4.9		− 1.5	
B 4_g	87.7		− 6.3		− 1.9	
R 3_c[a]	63.0		+29.5		+ 1.8	
R 3_g	61.5		+30.1		− 0.9	
R 2_H	58.4		+34.0		+ 2.4	
		−0.2		+0.3		+ 0.3
R 2_c	58.6		+33.7		+ 2.1	
R 2_g	57.1		+34.7		− 0.3	
R 4_H	71.8		+19.9		+ 1.9	
		+0.2		+0.2		+1.1
R 4_c	71.6		+19.7		+ 0.8	
R 4_g	70.0		+20.7		− 1.1	
R 1_H	79.6		+12.1		+ 2.6	
		+0.8		0.0		+ 1.5
R 1_c	78.8		+12.1		+ 1.1	
R 1_g	77.9		+12.9		− 0.7	
R 5_H	87.9		+ 3.8		+ 3.9	
		+1.5		−0.7		+ 2.8
R 5_c	86.4		+ 4.5		+ 1.1	
R 5_g	86.0		+ 4.8		+ 0.1	

[a] Standard.

than a least perceptible difference. These two series did not involve much change in the blue portion of the spectrum and, hence, the error in the *b* scale is not conspicuous. Perhaps the improved results are indicative

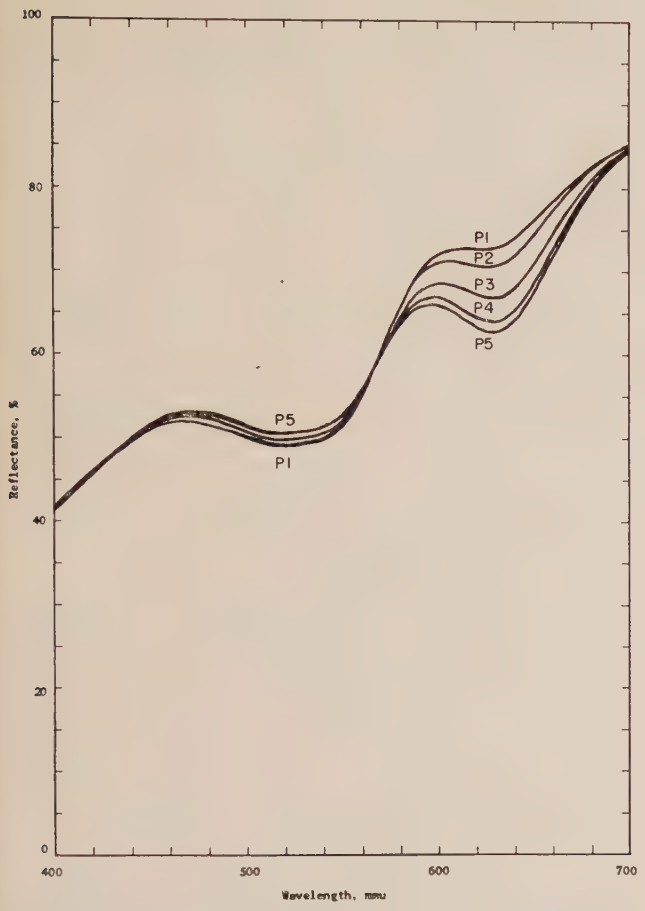

Fig. 12. Spectral reflectance of family of five pink paper samples

of the better quality of matching that might be obtained if the accuracy of the *b* scale were improved.

Summary

Various tests, conducted to determine the accuracy of the Hunter Color and Color-Difference Meter, show that, in general, a source of error caused an appreciable discrepancy in the *b* scale of the particular instrument investigated. These tests included measurements on a series of white papers, a series of Corning and Wratten filters, a family from this group of yellow filters, a series of five families of dye solutions (nonmetameric), and a series of two families of nonmetameric colored papers. In all but the last series, the majority of discrepancies were objectionably large, being equivalent to many least perceptible differences. The larger discrepancies are apparently attributable to poor fitting of the blue filter system in the HCDM to that theoretically required; it appears that the error, expressed in terms of the centroid wavelength is about −10 mmu. The series of tests with the families of pink and green papers resulted in good agreement with the calculated values; it happened, in these cases, that the nature of the curves was such that the changes in the *b* values were small, and this is taken as an indication that the instrument could be satisfactorily accurate if the spectral errors were largely eliminated.

Table XVI. Tristimulus and Calculated Hunter Values for the Pink and Green Paper Series

Sample	X	Y	Z	*Rd*	a	b
P 1_6	0.6218	0.5820	0.5946	58.2	+12.0	+7.2
P 2_3	0.6126	0.5777	0.5927	57.8	+10.9	+7.0
P 3_3	0.6014	0.5756	0.5997	57.6	+ 8.8	+6.3
P 4_2	0.5932	0.5736	0.6018	57.4	+ 7.3	+5.9
P 5_1	0.5874	0.5703	0.6024	57.0	+ 6.7	+5.6
Gr 1_4	0.4970	0.5686	0.6396	56.9	−14.4	+2.5
Gr 2_5	0.4896	0.5610	0.6400	56.1	−14.5	+1.8
Gr 3_3	0.4820	0.5538	0.6424	55.4	−14.8	+0.9
Gr 4_2	0.4650	0.5368	0.6331	53.7	−15.1	+0.1
Gr 5_5	0.4541	0.5247	0.6299	52.5	−15.0	−0.9

SECTION V. CONCLUSIONS

The principal concern in this study relates to the question of whether or not the Hunter Color and Color-Difference Meter would be satisfactory for the production control of color, and to how the instrument might be improved. Again, the supposition is made that one is interested only in the matter of controlling the color,

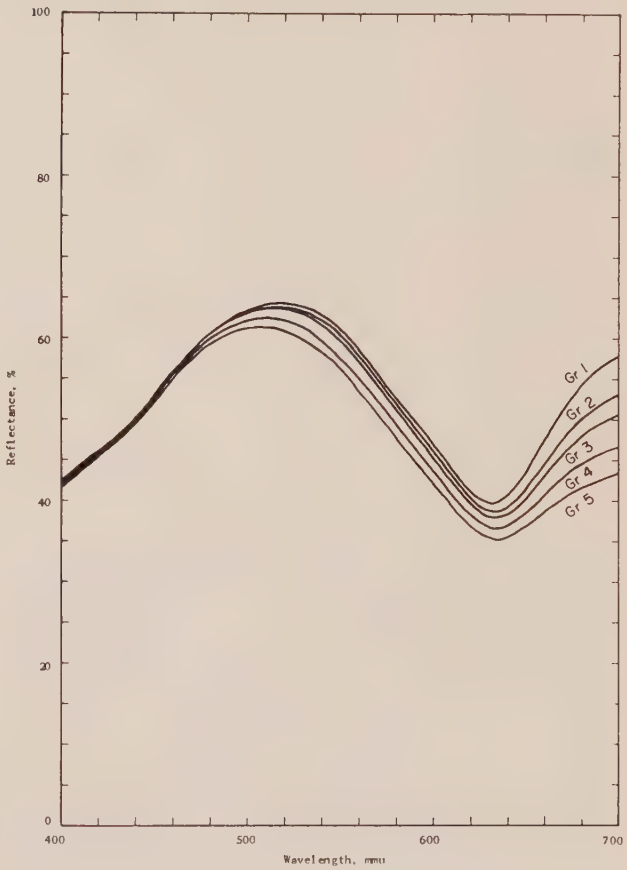

Fig. 13. Spectral reflectance of family of five green paper samples

and that he is willing to forego the analytical advantages of spectrophotometry in favor of obtaining rapid colorimetric values. For example, it is supposed that one will not expect this instrument to yield a spectral reflectance curve or such specialized reflectances as papermakers' brightness, because such information may not be obtained with the HCDM.

The HCDM is definitely a promising but not yet satisfactory device for the mill control of color. The particular instrument studied (made for the purposes of trial by various possible users) was found to have a few significant defects, some of which should be lessened or eliminated to yield adequately accurate data on color differences. The most serious defect was found in the indication of *b* values (which relate to yellowness and blueness). Large errors were found in the *b* scale, even when the color standard and the specimen were nonmetameric—that is, had spectrophotometric curves of similar form. These errors could be explained if the centroid wavelength of the spectral response of the instrument (for the blue reflectance) were about 10 mmu

Table XVII. Summary of Data on the Pink and Green Series

Sample	Rd	Rd Difference	a	a Difference	b	b Difference
Standard						
P 1_6	58.2		+12.0		+7.2	
P 2_{3H}	58.0		+11.0		+7.0	
		+0.2		+0.1		0.0
P 2_{3C}	57.8		+10.9		+7.0	
P 3_{3H}	57.4		+ 8.9		+6.2	
		−0.2		+0.1		−0.1
P 3_{3C}	57.6		+ 8.8		+6.3	
P 4_{2H}	57.3		+ 7.2		+5.8	
		−0.1		−0.1		−0.1
P 4_{2C}	57.4		+ 7.3		+5.9	
P 5_{1H}	57.2		+ 6.5		+5.5	
		+0.2		−0.2		−0.1
P 5_{1C}	57.0		+ 6.7		+5.6	
Standard						
Gr 1_4	56.9		−14.4		+2.5	
Gr 2_{5H}	55.1		−14.9		+1.3	
		−1.0		−0.4		−0.5
Gr 2_{5C}	56.1		−14.5		+1.8	
Gr 3_{3H}	54.7		−14.9		+0.4	
		−0.7		−0.1		−0.5
Gr 3_{3C}	55.4		−14.8		+0.9	
Gr 4_{2H}	53.8		−14.8		−0.6	
		+0.1		+0.3		−0.7
Gr 4_{2C}	53.7		−15.1		+0.1	
Gr 5_{5H}	51.8		−14.8		−1.9	
		−0.7		+0.2		−1.0
Gr 5_{5C}	52.5		−15.0		−0.9	

less than the proper value. This is seen to be a large wavelength error in an instrument that is based on a method which, at best, is somewhat "color blind" (*3*). Although smaller, errors in the *a* scale were unduly large, being occasionally of the order of, or greater than, a NBS unit for nonmetameric combinations of color standard and specimen. Errors of the circuit or of the adjustment of the photocell response may have been more directly responsible for these errors than a mismatch of the spectral response function.

In the "Description and Instructions for Hunter Color and Color-Difference Meter," Hunter states, "In the detailed paper (*5*) it is shown that for the measurement of a large color interval (between white standard and a strong green, blue, or red specimen), the error in terms of the fundamental scales defined in equations (1) is likely to total 4 units and the disagreement between one color difference meter and another is likely to total 2.5 units. For a small color interval between standard and sample of similar color, however, the error and disagreement drop to about 0.2 unit . . ." These claims were not substantiated in the present study. Where there was a strong difference between the color of the standard and a specimen (see, e.g., Table XI), the error in total color difference [computed by means of equation (3)] was found to be as large as 19 units and the spread in this error was about 30 units. In one series of yellows (see Table XII), where the standard and specimens had similar colors, the error in total color difference was, in one case, 16.8 units and, for two curves that were quite close together, the error was 2.3 units (about ten times the claimed error of about 0.2). Further evidence for the failure of the instrument reliably to indicate color differences between specimens and a standard having similar color curves is to be found in Table XV, in which the results are given for five families of dye solutions.

To be sure, the errors would diminish when the differences between the color curves of the standard and the specimen are made smaller. However, it is not sufficient merely to specify that the color difference between the standard and the specimen be small; the color curves must "parallel" each other in the sense discussed in the text of this report, and the difference in reflectance must not be large. It would be difficult for a user of the instrument to ascertain when he has met these requirements, if he could not study his problem with a spectrophotometer.

It seems likely that the HCDM could be satisfactorily employed for color matching (when the foregoing requirements are met) if the error in total color difference could be reduced to a few units (as claimed) when there is a wide disparity between the color curves for the color standard and the specimen. The results presented in Table XVII, for materials having small *b* values (and for which the errors in *b* were relatively small), are perhaps indicative of the quality of results that could be generally obtained in the measurement of differences between the colors of materials having closely similar spectral reflectance curves, were the instrument to be improved.

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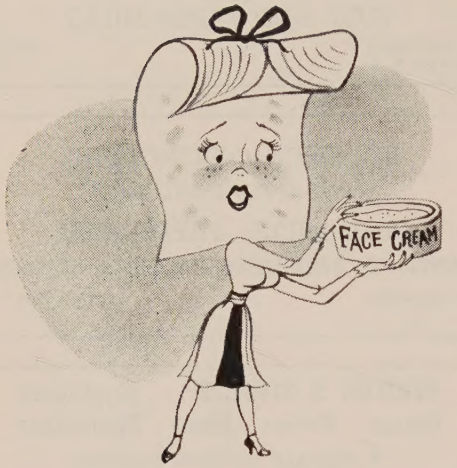
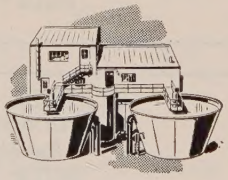


ARE YOU bothered by streaks and speckles on your paper's face?

You can prevent them by installing Permutit water conditioning equipment. A constant supply of soft water will wash away the blotches in your paper's complexion caused by iron, dirt and other impurities ...and it will make production run more smoothly, too.

Permutit Equipment Gives You Complete Control of Water Quality



Whatever your local water conditions, Permutit can provide you with soft, clear process water, tailor-made to your individual requirements.

Write for full information about economical Permutit equipment to The Permutit Co., Dept. TAPPI, 330 West 42nd St., New York 18, N. Y., or to Permutit Company of Canada, Ltd., 6975 Jeanne Mance Street, Montreal.

Water Conditioning Headquarters for Over 38 Years

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Equal to 200,000 trees 10" in diameter

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for cutting and loading

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